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THESIS

REALIGNMENT OF
THE U.S. ARMY RECRUITING COMMAND

by

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September 1992

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This thesis addresses two problems of concern by the U.S. Army Recruiting Command: the realignment of recruiting battalions and companies. For the realignment of the recruiting battalions, this thesis identifies four realignment criteria: (1) Proper trade-off between size and density; (2) State ownership; (3) Adequate command presence; (4) Robustness with respect to shifts in population. In addition, it demonstrates that the realignment based on state boundary satisfies the four criteria and is a strong candidate for implementation by the command.

For the realignment of recruiting companies, this thesis provides an optimization model to realign the companies and two statistical forecasting models to predict the size of the future recruiting market in each battalion. When implemented, the combination of the optimization and statistical models can assist the staff members at the Recruiting Command in the realignment of their recruiting companies

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Realignment of the U.S. Army Recruiting Command

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of the requirements for the degree

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ABSTRACT

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I. INTRODUCTION

A. BACKGROUND

The threat of a large scale war involving US forces has been vastly reduced as a result of the recent decomposition of the Soviet Union together with the sound defeat of the Iraqi military by coalition forces in 1991. With the perceived reduction of the threat to our own security, as well as with the security of close allies, the US has begun a large scale draw down of the size of its military forces.

The army intends to reduce its active component alone by 25 percent before September 1995. This level of reduction is in addition to the nine percent reduction the army has already taken since September 1989. [Ref. 1] The initial force reduction was met mostly through normal attrition. However, further downsizing of active army forces will be met largely through reducing the number of young men and women accessing into the force [Ref. 1:p. 77].

At the U.S. Army Recruiting Command (USAREC), this downsizing translates into fewer numbers of recruits to be enlisted into the Army annually. A smaller number of recruits may appear to reduce the recruiting effort at USAREC. However, the opposite is true. In fact, having to recruit fewer people means that USAREC must be more selective about who can enlist into the Army. Moreover, the ever-increasing sophistication of weapons and support systems together with intelligent employment of these systems mandates that only the best and brightest be

allowed to enter the force [Ref. 1: p. 18]. Since the start of the downsizing process, USAREC has been focusing its efforts on quality applicants. These applicants must possess a valid high school diploma or must be a senior in the process of obtaining one. In addition, they must have also scored in the upper half of the Armed Services Vocational Aptitude Battery (ASVAB) test.

Along with the increased quality requirement, the shrinking defense budget also makes the task of recruiting more difficult. The operating budget and the size of USAREC must be drastically reduced along with other agencies in the Army. Consequently, USAREC must recruit for higher quality enlistees in a very competitive market with fewer personnel, support and advertising assets. Thus, the goal of this thesis is to investigate methods which identify the most effective and efficient utilization of resources available to USAREC.

B. ORGANIZATIONAL STRUCTURE AND RECENT EVOLUTION OF THE COMMAND

USAREC is charged with one of the most important missions of any organization in the Army. Its primary mission is to recruit men and women to fill the enlisted ranks of both active duty and United States Army Reserve (USAR) units. Other missions involve recruiting officers for the Army Nurse Corps, and for certain other officer programs, both commissioned and warrant.

1. Organizational Structure

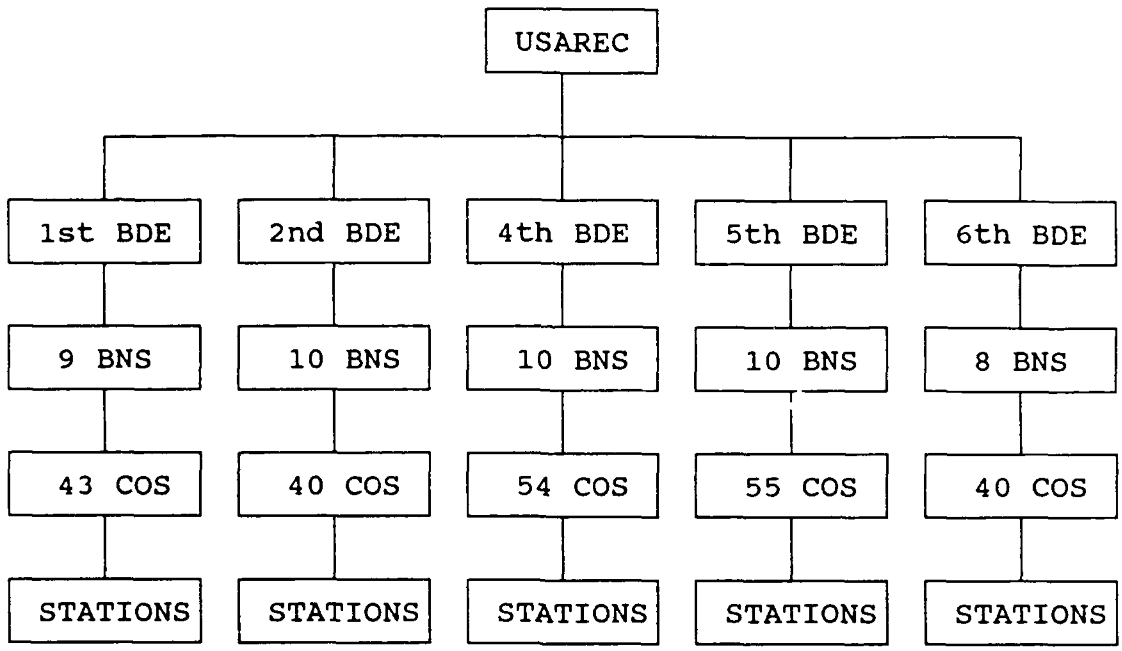
USAREC has recruiting stations located in every state, in overseas locations near key military installations, and in many of the US territories.

Recruiting stations are at the bottom of the command structure in USAREC and are where the enlistment process begins. The stations are charged to a senior non-commissioned officer who, together with one or more recruiters, conduct the recruiting activities. Stations have an assigned geographical area - or recruiting market - in which they are responsible to recruit, generally composed of zip codes and/or entire counties or groups of counties.

The next higher level of command is the recruiting company. Each company supervises the recruiting activities of six to ten recruiting stations. Geographically, a company is responsible for the markets of the recruiting stations under its supervision. Thus, the geographical size of a company can range from a fraction of a county in a densely populated metropolitan area to a number of counties in rural or semi-rural areas.

Between three and seven recruiting companies are grouped together to form the next higher level of command: the recruiting battalion. The battalions vary tremendously in geographical size. For example, the Chicago Recruiting Battalion is composed of 13 densely populated counties in the metropolitan Chicago area and in Northern Indiana, whereas the Salt Lake City Battalion contains the entire states of Utah and Montana, the majority of Idaho, large parts of Wyoming, Oregon, Nevada, and a part of Northwest Arizona.

The highest level of command beneath the USAREC headquarters is the recruiting brigade. Figure 1 displays the current organizational chart of the Recruiting Command.



NOTE: BDE = Brigade; BNS = Battalions; COS = Companies

Figure 1 Current Organizational Chart Of USAREC

As shown, there are five brigades (note that Third Brigade does not exist). The current number of battalions and companies under each brigade are also listed in Figure 1. By the fourth quarter of FY 92, there are 1670 stations under the 221 companies. The current configuration of the 47 battalions is shown on the map in Figure 2.

2. Recent Evolution of the Command

The size and structure of USAREC has varied over the years, expanding and contracting as the strategic and military situation of the nation has dictated. The composition of the command has changed quite drastically over the past few years

on its way to becoming a smaller and leaner organization. Table 1 shows the reduction of the number of commands at all levels in USAREC during recent years. The reduction in the number of commands during the period covered in Table 1 has been USAREC's response to the reduction in budget levels. The current reduction (draw down) started in FY 90 and is a multi-phased operation. USAREC has recently executed Phase IV at the end of 3rd Quarter of FY 92, in which a substantial reduction in the number of commands at all levels took place as shown in Table 1.

TABLE 1 NUMBER OF COMMANDS IN RECENT YEARS

LEVEL	FY 90	FY 91	FY 92
BRIGADE	5	5	4
BATTALION	55	47	42
COMPANY	261	232	221
STATION	2027	1746	1670

NOTE: Figures indicate levels at end of fiscal year. The reduction in FY 92 occurred at the end of the 3rd Quarter.

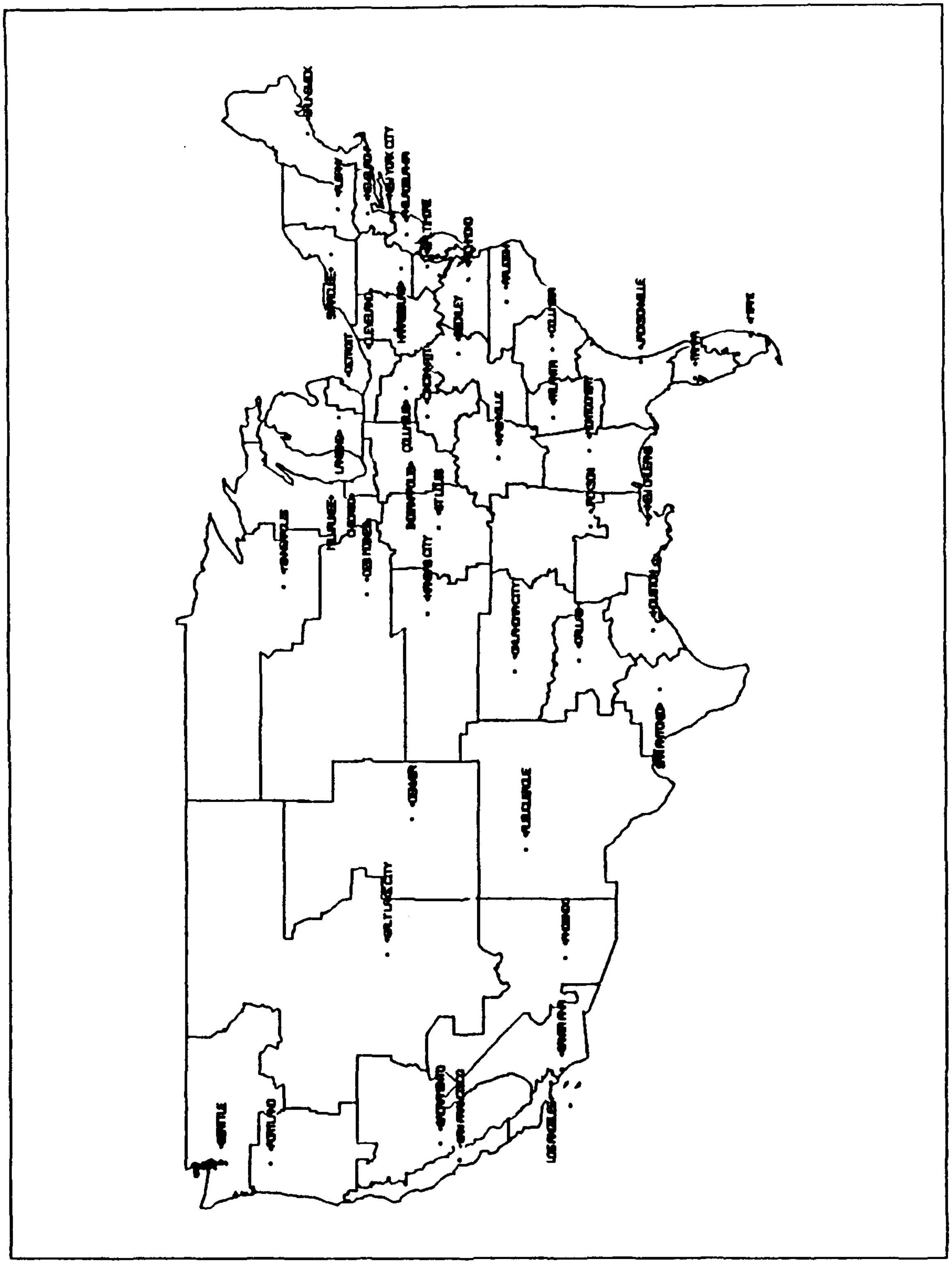


Figure 2 Current 47 Battalion Configuration

C. THE ONGOING REORGANIZATION: DOWNSIZING OF USAREC

Given the chain of world events discussed earlier, the budget for USAREC will become even smaller, requiring further reduction of the command. Its downsizing efforts must achieve the intended results quickly, as its vital mission can not tolerate inefficiency. USAREC is deeply concerned with balancing the downsizing effort while maintaining a viable recruiting force for the 90's and beyond. According to its operation order, the mission is to "Realign the U.S. Army Recruiting Command for successful and efficient recruiting in the 1990's [Ref. 2: p. 2]."

This includes:

- Reducing the number of command and control nodes. The nodes referred to are the companies, battalions and brigades discussed earlier, shown in Figure 1. The number of nodes effective Phase IV is shown in Table 1 under FY 92.
- Realigning the structure of the command at all levels.

The reduction and realignment is intended to help USAREC perform its mission with a decreasing budget and reduced number of personnel. Future phases will be required to further reduce the number of nodes, thereby reducing personnel levels and costs.

D. THESIS OBJECTIVE

To assist USAREC in its reorganization, this thesis addresses the problem of reducing the number of battalions and companies to the level needed beyond Phase IV of the downsizing process. For the reduction at the battalion level, there exists a natural boundary by which the battalions can be realigned. Then, the company

headquarters and boundaries are restructured to conform with the new battalion realignment.

The restructuring of companies can be stated as an integer programming problem similar to the uncapacitated plant location problem [Ref. 3: pp. 960-979]. The solution to this problem identifies optimal locations of company headquarters and allocation (or assignment) of counties to the headquarters. The thesis considers realignment of active duty recruiting only in the Continental United States (CONUS), as Alaska, Hawaii and other non-CONUS locations are currently assigned to CONUS based battalions as companies or recruiting stations.

E. THESIS ORGANIZATION

Chapter II presents the realignment of recruiting battalions. Based on this realignment, Chapter III develops an optimization model to realign recruiting companies within the boundary of each battalion. This optimization model requires data which must be forecasted based on the information currently available. The forecast is based on regression models presented in Chapter IV. Then, Chapter V implements and analyzes the results from the realignment of the Raleigh, North Carolina Recruiting Battalion. Finally, Chapter VI summarizes the thesis and recommends areas for further studies.

II. BATTALION REALIGNMENT

In the previous chapter, Figure 2 displays the alignment of the 47 battalions before the end of June 1992. At the end of June 1992, the number of battalions was reduced to 42. However, USAREC planners believe that 36 battalions are more compatible with the future budget levels and recruiting missions. This chapter proposes an alignment for the 36 battalions.

A. CRITERIA OF BATTALION ALIGNMENT

After considerable discussion with USAREC planners, it is determined that the following criteria should be considered when aligning battalions.

1. Size and density

In order to achieve effective and efficient recruiting, a battalion should ideally be allocated a region which has a small geographical size and a high density of 17-21 year old youths (the target population for recruiting). A small geographical area allows the battalion leadership to have more control and to provide closer supervision of the companies under the battalion. This promotes recruiting efficiency for the battalion.

Similarly, high density of the target population both simplifies and makes the recruiting effort more efficient. Recruiting typically entails visiting candidate enlistees (applicants) at their home or school, and making numerous other trips for administrative and other recruiting related purposes. Areas with a high density target

population then implies a reduction in driving time needed to visit an applicant's home or school, as well as time for making other trips. In addition, in such high density areas, recruiters can accomplish several objectives in one short trip, resulting in efficient use of time and resources.

In aligning battalions with the entire continental United States, it would be impossible to always allocate a small geographical region with a high target population density to every battalion. In fact, the general population of the Western United States tends to spread out over large geographical regions with a few exceptions, whereas the population in the northeast is heavily concentrated in and around several metropolitan areas. Thus, in the past, USAREC planners must have implicitly allowed for some degree of trade-off between size and population in aligning battalions. Consequently, the new alignment should conform to the previous and accepted trade-off between size and density of the target population.

2. State Ownership.

In order to facilitate recruiting at the station level, battalion commanders and staffs should maintain a close relationship with officials of pertinent state agencies, in particular the State Department Of Education and the Army National Guard (the National Guard is not affiliated with Army recruiting). In aligning the 36 battalions, it is desired that agencies in each state deal with a single representative from USAREC at the battalion level. This is to avoid confusion and simplify communications between the state authorities and the responsible Army recruiting battalion.

Under the current alignment of the existing 47 battalions, there are five battalions (Chicago, St. Louis, Indianapolis, Milwaukee and Des Moines) recruiting in Illinois, yet only one battalion, the Chicago battalion, has its headquarters in the state. The current partitioning of Illinois is displayed in Figure 3. Thus there are five separate battalions with which the state authorities must coordinate/interact, thereby complicating the communication process and inhibiting the Army from having one unified representation in a state. Therefore, to avoid potential problems and to streamline the communication link between state agencies and Army recruiting, it is desired that each state be assigned to or "owned" by a single battalion.

3. Insure Adequate Presence.

When a battalion is responsible to recruit in several states, it may unintentionally give a disproportionately large amount of attention to states which yield a higher number of recruits. However, this leaves other states (those having lower yields) with less command presence. Thus, to prevent such an occurrence, a battalion should be responsible for as few states as possible. This allows a battalion to focus its attention and resources more effectively.

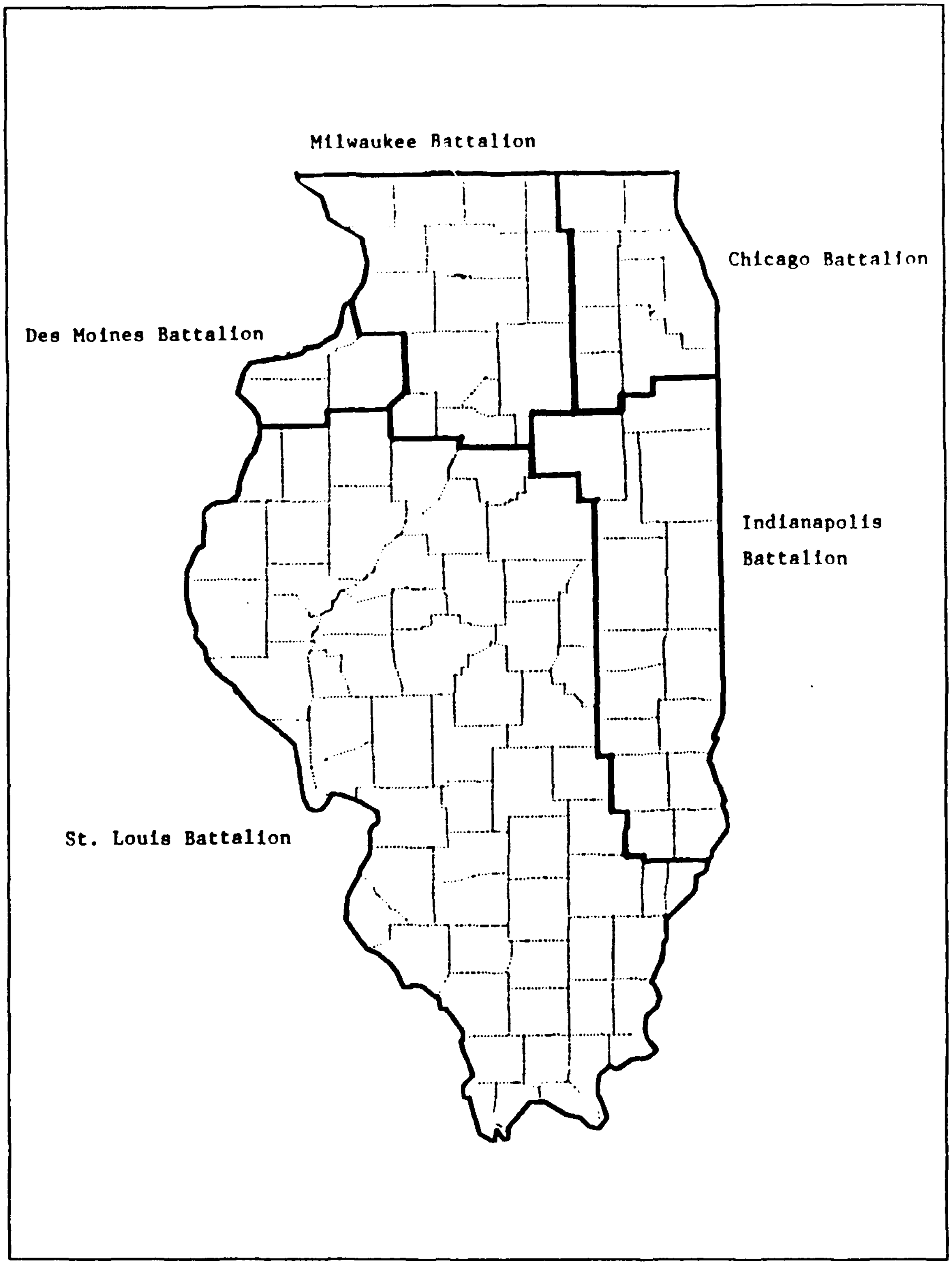


Figure 3 Current Battalion Level Partitioning of Illinois

4. Robust With Respect to Shifts in Population.

Since the decision to open, close and change a battalion requires considerable effort, it is desired that the new alignment be robust with respect to shifts in population. That is, slight changes in the population of one battalion should not drastically affect the alignment of companies or stations in any other battalion. Instead, it should affect only the battalion in question. Thus, planners should be able to make changes in one recruiting battalion without having the changes cascade over to other battalions.

B. ALIGNMENT BY STATE BOUNDARY

Using the above set of criteria, it is proposed that the 36 new battalions be aligned by state boundary. Whenever possible, a whole state is assigned to one battalion. In a few cases, a state may be partitioned such that each partition is assigned to different battalions in order to achieve the desired trade-off between size and density (the first criterion). The proposed alignment, using projected 17-21 year old population projection data [Ref. 4], is shown in Appendix A.

Figure 4 shows the proposed alignment of the 36 battalions on a map. Visually, this figure displays the trade-off between size and population density since the battalions in the West cover a large amount of territory, whereas the battalions in the East cover less, but more densely populated territory.

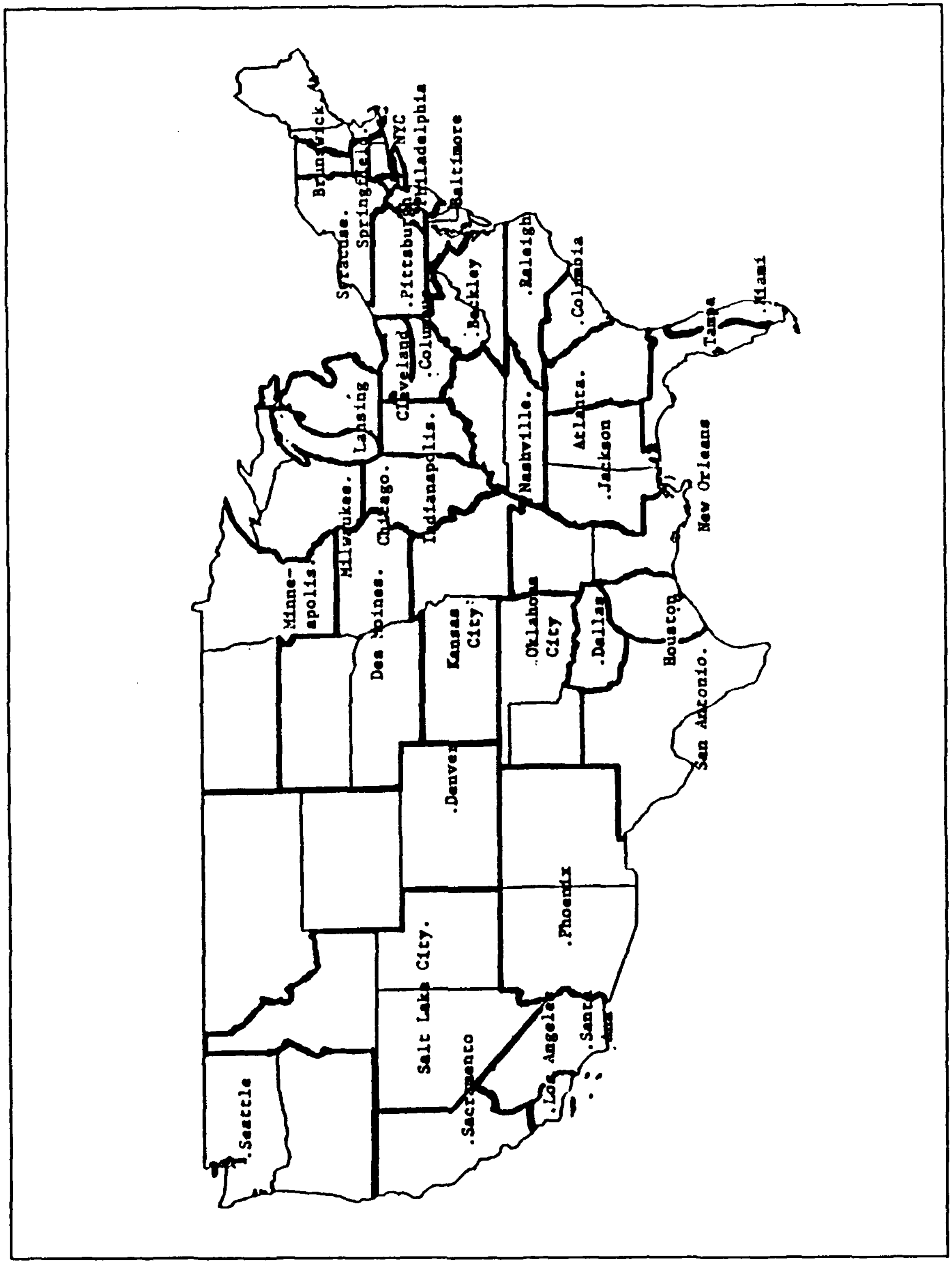


Figure 4 Map of the New 36 Battalion Alignment

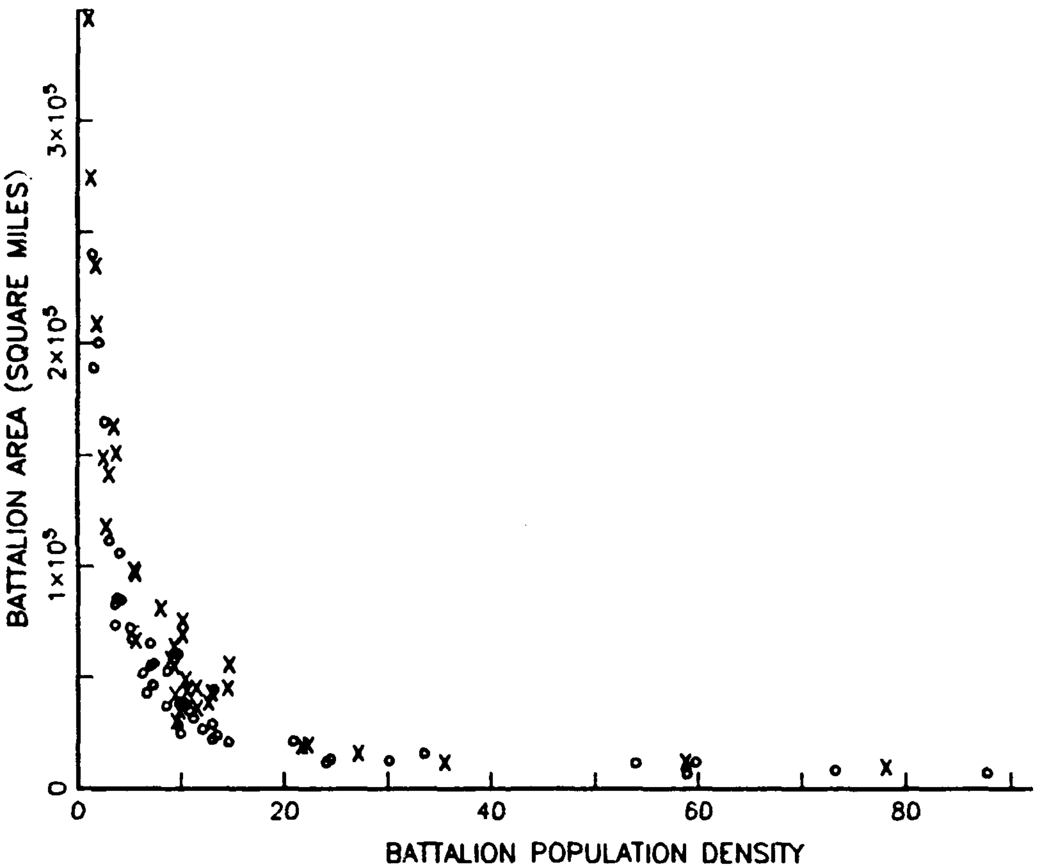
To evaluate the new alignment, Figure 5 compares the trade-off between size and density of the current (47 battalions) and proposed alignments. It is clear from this figure that the two alignments provide a similar trade-off, thereby satisfying the first criterion.

Table 2 shows that under the proposed alignment, the number of states being recruited by more than one battalion is relatively small when compared to the current alignment. Thus, the new alignment vastly improves the degree of state ownership and provides more states with a single Army recruiting representative, thereby fulfilling criterion two.

TABLE 2 NUMBER OF BATTALIONS BY STATE

CURRENT ALIGNMENT		PROPOSED ALIGNMENT	
NUMBER OF BNS IN THE STATE	NUMBER OF STATES	NUMBER OF BNS IN THE STATE	NUMBER OF STATES
5	2	5	0
4	7	4	1
3	11	3	1
2	16	2	6
1	12	1	40

NOTE: The number of battalions (BNS) in the state is the number of battalions having responsibility to recruit in at least one county in the state.



NOTE: o - represents 36 battalion configuration
x - represents 47 battalion configuration

(some battalions not plotted due to scale)

Figure 5 Battalion Area Versus Population Density

Table 3 demonstrates that over 80 percent of the battalions under the new alignment own (recruit in) no more than two states, and no battalions recruit in more than four states. Hence, the majority of the battalions can focus their recruiting efforts and coordination with state level authorities in two states or less, thereby meeting the requirement of criterion three.

TABLE 3 BATTALION BY STATE SUMMARY

CURRENT ALIGNMENT		PROPOSED ALIGNMENT	
# OF STATES IN THE BN	NUMBER OF BNS	# OF STATES IN THE BN	NUMBER OF BNS
7	1	7	0
6	0	6	0
5	4	5	0
4	3	4	1
3	12	3	5
2	13	2	11
1	14	1	19

NOTE: The number of states in the bn means that the battalion recruits in all or portions of that number of states

Besides the above quantifiable advantages of the proposed alignment method over the current one, alignment by state boundary also allows demographic changes to affect the structure solely internal to each battalion. This implies that when there is an increase or decrease in the population of a given state, only the internal organizational structure of the battalion - the alignment of companies and stations and assignment of recruiting areas thereof - needs to be modified. This reduces the

workload of everyone involved in the affected recruiting battalion, planners in the commands above the battalion level, and personnel in adjacent battalions who would have otherwise been affected by the changes.

Under the proposed alignment of battalions, the next chapter presents an integer programming model which produces an optimal realignment of the companies within a given battalion.

III. COMPANY REALIGNMENT

Given that the 36 battalions have been aligned, the problem of aligning companies in a battalion involves locating company headquarters and allocating recruiting responsibility to each company. This chapter provides an optimization model (problem) which selects the best locations for company headquarters as well as provides an optimal allocation of recruiting responsibility.

A. MODEL ASSUMPTIONS

To make the optimization model more manageable, the following assumptions are made:

1. Candidate Company Locations

The possible or candidate locations for company headquarters are known or are provided by USAREC personnel. The candidate locations can consist of existing companies and also of potential locations selected by the USAREC marketing branch. These potential locations typically combine two or more existing companies for better access to the recruiting market and recruiting stations assigned to them. Also, assumed to be known is the number of company headquarters to be established or opened in a given battalion.

2. Allocating Areas

The region within each battalion is subdivided into counties. In some special cases, a county may be further subdivided into several sub-counties. Then, to allocate recruiting responsibility is to assign counties (or sub-counties) to each of the companies (or opened company headquarters) in the battalion.

3. Allocation of Recruiting Responsibility

To insure that the allocation of recruiting responsibility is equitable among the companies, a measure of recruiting workload in a given county is used. This measure is based on two factors: the **predicted** number of *quality* and *volume* contracts in a given county. A *quality* contract is an enlistee who has or will have a valid high school diploma and scores in the upper half of the Armed Services Vocational Aptitude Battery (ASVAB). (The ASVAB is a standardized test administered by the military to determine an applicant's mental category.) A *volume* contract is an enlistee who meets the minimum ASVAB score required for enlistment eligibility. Note that a quality contract is also a volume contract; however, the converse is not true. Then, the allocation of workload responsibility is equitable if the total number of quality and volume contracts in the counties assigned to each company are approximately the same.

B. PROBLEM DESCRIPTION

The problem of aligning the companies in a given battalion can be separated into two parts. The first part involves choosing the desired number of locations

among the candidates to open company headquarters. Once the locations of the company headquarters are known, the second part of the problem is to assign counties (and the corresponding recruiting responsibility) to each of the company headquarters.

The choice of locations and assignment should satisfy two main objectives. The first objective is that company headquarters should be centrally located with respect to their assigned counties as measured in distance as well as the population density of the target market, i.e., the 17 - 21 year old age group. The second objective is to maximize the degree of equity of the recruiting responsibility. In the next section, this problem is formulated as a mixed integer programming problem which is known in operations research literature as the uncapacitated plant location problem. [Ref. 3]

C. PROBLEM FORMULATION

INDICES:

- i = county in the battalion under consideration
- j = candidate location of company headquarters (HQ) in the battalion under consideration

DATA:

D_{ij}	= distance from county i to candidate location j
V_i	= value assigned to county i
$OPEN_j$	= cost to open a HQ at candidate location j. (= 0 if j in an existing HQ location)
$CLOSE_j$	= cost to close a HQ at candidate location j. (= 0 if j is a new HQ location)
$PQUAL_i$	= predicted number of quality contracts available in county i. (See discussion in Chapter IV)
$PVOL_i$	= predicted number of volume contracts available in county i. (See discussion in Chapter IV)
NHQ	= desired number of HQ in the battalion under consideration
QGOAL	= desired number of quality contracts allocated to each company (workload)
VGOAL	= desired number of volume contracts allocated to each company (workload)
PENQUAL	= penalty for deviation from the desired number of quality contracts (QGOAL) for each company
PENVOL	= penalty for deviation from the desired number of volume contracts (VGOAL) for each company
AVGQUAL	= average number of predicted quality contracts in a county
VAR	= maximum allowable deviation from the desired number of contracts

VARIABLES:

X_{ij} = binary (= 1 if county i is assigned to candidate location j and 0 otherwise)

Y_j = binary (=1 if candidate location j is used and 0 otherwise)

ZP_j = number of quality contracts in excess of the desired number (QGOAL)

ZM_j = number of quality contracts short of the desired number (QGOAL)

WP_j = number of volume contracts in excess of the desired number (VGOAL)

WM_j = number of volume contracts short of the desired number (VGOAL)

OBJECTIVE:

$$\text{MINIMIZE} \quad \sum_i \sum_j V_i * D_{ij} * X_{ij}$$

$$+ PENQUAL * \sum_j (ZP_j + ZM_j)$$

$$+ PENVOL * \sum_j (WP_j + WM_j)$$

$$+ \sum_j OPEN_j * y_j + \sum_j CLOSE_j * (1 - Y_j)$$

CONSTRAINTS:

$$\sum_j Y_j = NHQ \qquad (1)$$

$$\sum_j X_{ij} = 1, \quad \forall\, i \qquad (2)$$

$$X_{ij} \leq Y_j, \quad \forall\, i, j \qquad (3)$$

$$X_{ij} = Y_j, \quad \forall i, j\text{:} \quad d_{ij} = 0 \qquad (4)$$

$$\sum_i (PQUAL_i * X_{ij}) + ZP_j - ZM_j = QGOAL * Y_j, \quad \forall\, j \qquad (5)$$

$$\sum_i (PVOL_i * X_{ij}) + WP_j - WM_j = VGOAL * Y_j, \quad \forall\, j \qquad (6)$$

$$0 \leq ZP_j \leq VAR * QGOAL, \quad \forall\, j \qquad (7)$$

$$0 \leq ZM_j \leq VAR * QGOAL, \quad \forall\, j \qquad (8)$$

$$0 \leq WP_j \leq VAR * VGOAL, \quad \forall\, j \qquad (9)$$

$$0 \leq WM_j \leq VAR * VGOAL, \quad \forall\, j \qquad (10)$$

D. MODEL DISCUSSION

The objective function to be minimized consists of five terms. The first term is the sum of weighted distances from each county to its assigned headquarters. The weight generally depends on the "desire" to recruit in or value assigned to a county. The second and third terms are the penalties assessed for being over or under the desired number of quality (QGOAL) and volume (VGOAL) contracts, respectively. Higher values of PENQUAL and PENVOL yield smaller deviations from the desired numbers. Finally, the last two terms represent the cost for opening new company headquarters and closing the old ones.

Constraint (1) insures that the desired number of company headquarters (NHQ), are opened. Constraints (2) through (4) address the assignment of counties to company headquarters. In particular, constraints (2) and (3) together assign each county to exactly one headquarters that is designated to be opened. Constraint (4) assigns a county to the headquarters in which it is located.

The remaining constraints are concerned with the workload assigned to the companies. The annual workload assigned to the companies is the number of quality and volume contracts that a company can expect to achieve. Though workload equity between the companies is desirable, it can not always be attained because of the differences in the expected number of contracts from the counties assigned to the various companies. Constraints (5) and (6) calculate the workload differences between the companies, and the objective function penalizes deviations from the standard workload (QGOAL and VGOAL). Finally, constraints (7) through (10)

insure that the workload for a company is not too high or too low relative to the other companies by providing a bound on the deviation from the standard workload for each company.

Since the realignment of battalions and companies must be suitable for future recruiting efforts, the input data to the optimization model presented here must reflect the future recruiting environment. The year 1995 is chosen because of the availability of data; however, it also represents planning for the future beyond Phase IV of the current realignment process. The next chapter presents regression models for predicting the annual contract yields in each county ($PQUAL_i$ and $PVOL_i$) for 1995.

IV. PREDICTING QUALITY AND VOLUME CONTRACTS FOR 1995

The optimization model in the previous chapter requires the number of quality and volume contracts in each county in the year 1995. Regression models are used to predict these values. Recall that the quality and volume contracts are defined previously as follows:

- **Quality contracts** = the number of enlistees (from all branches of service) who have or will have a valid high school diploma *and* score in the upper half of the ASVAB.

- **Volume contracts** = the number of enlistees (from all branches of service) who have or will have a valid high school diploma *and* meet minimum ASVAB requirements.

Note that these numbers are the total numbers for all services, not just the Army, as they identify the total pool of all contracts. To avoid potential confusion between predicted and actual values, and to indicate the year, the following notation is used:

- $Q_{i,t}$ = *actual* number of quality contracts from county i in year t
- $V_{i,t}$ = *actual* number of volume contracts from county i in year t
- $PQUAL_{i,t}$ = *predicted* number of quality contracts from county i in year t
- $PVOL_{i,t}$ = *predicted* number of volume contracts from county i in year t

Thus, of interest in this chapter are $PQUAL_{i,95}$ and $PVOL_{i,95}$.

A. PREDICTOR VARIABLES

In order to estimate $PQUAL_{i,95}$ and $PVOL_{i,95}$, historical values of quality and volume contracts as well as the following demographic and socio-economic factors are considered as candidate predictors:

- $T_{i,t}$ = target age market of county i in year t where the target age market refers to the population in the 17-21 year old age group in a particular county
- $E_{i,t}$ = average education level of the population in county i in year t
- $M_{i,t}$ = median family income of the population in county i in year t
- $U_{i,t}$ = percent unemployed in county i in year t

B. STATISTICAL MODELS

Since the data for quality and volume contracts and target age market vary over a large range of values, their values are transformed using the logarithmic function. One requirement for this transformation is that all observed values must be greater than zero [Ref. 5: p. 135], for the transformation is not well defined otherwise. When an observed value is zero, either a small constant is added or the observation is discarded. This thesis chooses the latter since the number of observations with zero value is relatively small and the number of observations with low contract values are more than sufficient to obtain statistically significant results.

Two types of models are explored: global and regional models. In the global models, it is assumed that the number of quality contracts for every county can be

described by a single (regression) model. This model predicts the number of quality contracts (in a future year) as a function of a subset of predictor variables mentioned in Section A. The same assumption also applies to the number of volume contracts.

In the regional model, the counties are grouped into four regions: northeast, south, midwest and west. Table 4 lists the states, hence the counties, in each of

TABLE 4 STATES ASSIGNED TO EACH REGION

NORTHEAST	SOUTH	MIDWEST	WEST
MAINE	DELAWARE	OHIO	MONTANA
NEW HAMPSHIRE	MARYLAND	INDIANA	IDAHO
VERMONT	WASHINGTON DC	ILLINOIS	WYOMING
MASSACHUSETTS	VIRGINIA	MICHIGAN	COLORADO
RHODE ISLAND	WEST VIRGINIA	WISCONSIN	NEW MEXICO
CONNECTICUT	N. CAROLINA	MINNESOTA	ARIZONA
NEW YORK	S. CAROLINA	IOWA	UTAH
NEW JERSEY	GEORGIA	MISSOURI	NEVADA
PENNSYLVANIA	FLORIDA	N. DAKOTA	WASHINGTON
	KENTUCKY	S. DAKOTA	OREGON
	TENNESSEE	NEBRASKA	CALIFORNIA
	ALABAMA	KANSAS	
	MISSISSIPPI		
	ARKANSAS		
	LOUISIANA		
	OKLAHOMA		
	TEXAS		

the four regions. The hypothesis here is that the number of quality (volume) contracts can be described using four separate linear regression models, one for each of the four regions.

1. Global Models

In the global models, it is assumed that under the logarithmic transformation, variation in quality and volume contracts can be partly explained by the predictor variables, i.e.,

$$\ln(PQUAL_{i,t})=\alpha_0+\alpha_1\ln(T_{i,t})+\alpha_2M_{i,t}+\alpha_3E_{i,t}+\alpha_4U_{i,t}+\alpha_5\ln(Q_{i,t-4})+\alpha_6\ln(Q_{i,t-5})+\epsilon_1$$

$$\ln(PVOL_{i,t})=\beta_0+\beta_1\ln(T_{i,t})+\beta_2M_{i,t}+\beta_3E_{i,t}+\beta_4U_{i,t}+\beta_5\ln(V_{i,t-4})+\beta_6\ln(V_{i,t-5})+\epsilon_2$$

where α_i and β_i are coefficients to be estimated. The random errors, ϵ_1 and ϵ_2, are assumed to be two independent normal random variables with zero mean. Notice that lagged variables $Q_{i,t-4}$, $Q_{i,t-5}$, $V_{i,t-4}$, and $V_{i,t-5}$ are included as predictors in addition to demographic and socio-economic factors. These lagged variables are investigated assuming that historical contract production is significant in helping to explain future contract production. The lag of four and five years in the number of quality and volume contracts, i.e., ($Q_{i,t-4}$, $V_{i,t-4}$, $Q_{i,t-5}$, and $V_{i,t-5}$) are limited by the availability of data. In particular, for t = 1995, there is currently no data available for the year 1992 (or t-3) to 1994 (or t-1). To overcome the unavailability of these data, current available data must be used to estimate the coefficients α_i and β_i. For this purpose, t is set to year 1990. Logically, the historical values for Q_i and V_i can be lagged more than five years. However, the Department of Defense instituted for the first

time in 1985 the GI Bill and College Fund programs in order to attract more quality enlistees. These programs had a major impact on recruiting and the recruiting data (Q_i and V_i) prior to 1985 are deemed inappropriate for this study.

Setting t = 1990, the data for 1990, 1986 (t-4) and 1985 (t-5) can be obtained from the Defense Management Data Center (DMDC) and the USAREC Marketing Branch. These data represent the information for 3120 counties in CONUS. Among them, 320 counties (approximately 10%) were randomly selected for the regression analysis. A summary of the counties selected, the states represented and other pertinent facts is given in Appendix B, and the actual data for all variables is in Appendix C.

Based on the data in Appendix C, the stepwise option of the PROC REG in SAS Version 6.07 [Ref. 6] is used to select influential predictors for quality and volume contracts. (A copy of the SAS file used to perform the regression analysis is in Appendix D.) Results of the stepwise analysis are provided in Tables 5 and 6.

TABLE 5 STEPWISE PROCEDURE RESULTS (LN $PQUAL_{i,t}$)

VARIABLE	PARTIAL R^2	MODEL R^2	F	P VALUE
LN $T_{i,t}$	0.9150	0.9150	3359.8097	0.0001
LN $Q_{i,t-4}$	0.0147	0.9297	65.1257	0.0001
LN $Q_{i,t-5}$	0.0026	0.9323	11.7007	0.0007
$E_{i,t}$	0.0014	0.9337	6.4833	0.0114

At the significance level $\alpha = 0.05$, Table 5 shows that the factors $\ln(T_{i,t})$, $\ln(Q_{i,t-4})$, $\ln(Q_{i,t-5})$ and $E_{i,t}$ are significant for predicting $\ln(Q_{i,t})$, whereas only the first three factors prove to be significant for $\ln(V_{i,t})$ in Table 6.

TABLE 6 STEPWISE PROCEDURE RESULTS (LN $PVOL_{i,t}$)

VARIABLE	PARTIAL R^2	MODEL R^2	F	P VALUE
LN $T_{i,t}$	0.9330	0.9330	4385.0626	0.0001
LN $V_{i,t-4}$	0.0147	0.9477	88.5449	0.0001
LN $V_{i,t-5}$	0.0010	0.9487	6.0182	0.0147

Based on the above results, two global models are tentatively chosen:

GLOBAL 1:

$$\ln(PQUAL_{i,t}) = -2.329 + 0.564\ln(T_{i,t}) + 0.254\ln(Q_{i,t-4}) + 0.166\ln(Q_{i,t-5}) \quad with R^2 = 0.9337$$

$$\ln(PVOL_{i,t}) = -1.971 + 0.524\ln(T_{i,t}) + 0.341(V_{i,t-4}) + 0.115(V_{i,t-5}) \quad with R^2 = 0.9487$$

GLOBAL 2:

$$\ln(PQUAL_{i,t}) = -3.917 + 0.963\ln(T_{i,t}) \quad with\ R^2 = 0.9150$$

$$\ln(PVOL_{i,t}) = -3.499 + 0.963\ln(T_{i,t}) \quad with\ R^2 = 0.9330$$

Global 1 models use the target age market, and lagged quality and volume contracts as predictors, while Global 2 models employ only the target age market as a predictor. In terms of R^2, predictability of these two models do not appear to be significantly different.

2. Regional Models

Regional models are formulated based on the Global 2 models. However, it assumes that each region may have different slope and intercept coefficients. To describe the regional models, define for each county i the following dummy variables:

- N_i = 1 if county i is in a northeastern state, and 0 otherwise
- S_i = 1 if county i is in a southern state, and 0 otherwise
- M_i = 1 if county i is in a midwestern state, and 0 otherwise
- W_i = 1 if county i is in a western state, and 0 otherwise

As defined, only one of the four variables can equal one for each county i since it can be in only one region. For example, if $N_i = 1$, then S_i, M_i, and W_i must all be zero.

Using the above "regional" or dummy variables, the entire data set can be used to estimate the regression coefficients for the four regions simultaneously. This method yields more accurate estimates than dividing up the data set into four groups and estimating the coefficients for each region separately. Using the dummy variables, the regional models for quality and volume contracts are as follows:

$$\ln(PQUAL_{i,t})=a_1N_i+a_2S_i+a_3M_i+a_4W_i+(b_1N_i+b_2S_i+b_3M_i+b_4W_i)\ \ln(T_{i,t})+\epsilon_1$$

$$\ln(PVOL_{i,t})=c_1N_i+c_2S_i+c_3M_i+c_4W_i+(d_1N_i+d_2S_i+d_3M_i+d_4W_i)\ \ln(T_{i,t})+\epsilon_2$$

where ϵ_1 and ϵ_2 are as defined previously and a, b, c and d are coefficients to be estimated by the regression. Using data from the same 320 counties, the regression procedure in SAS version 6.07 yields the following results:

$$\ln(PQUAL_{i,t}) = -1.9595N_i-4.6855S_i-3.5468M_i-3.1061W_i+(0.7550N_i+1.0510S_i+0.9244M_i+0.8718W_i)\ \ln\ (T_{i,t})$$

$$\ln(PVOL_{i,t}) = -2.2696N_i-3.7943S_i-3.5912M_i-2.7956W_i+(0.8319N_i+1.0000S_i+0.9719M_i+0.8808W_i)\ \ln\ (T_{i,t})$$

C. COMPARISON OF MODELS BY CROSS VALIDATION

In this section, the mean relative error (MRE) is used to compare the three chosen models: Global 1, Global 2, and Regional. Recall that MRE is defined as follows:

$$MRE = \frac{\sum_i |Y_i-\hat{Y}_i|}{Y_i}$$

where

Y_i = observed values (quality or volume contracts)

$\hat{Y}_i$ = predicted values (quality or volume contracts)

A random sample of 48 counties, one from each of the 48 contiguous states, is used for computing the MRE for the three models. This sample of 48 counties contains none of the 320 counties included in the first sample. Table 7 summarizes the results from the MRE calculations displayed in Appendix E.

Table 7 MEAN RELATIVE ERRORS

	GLOBAL 1	GLOBAL 2	REGIONAL
QUALITY	15.726	17.011	17.796
VOLUME	11.555	13.507	13.562

Since Global 1 provides the minimum MRE's, it is used to predict both quality and volume contracts for the implementation described in the next chapter. Note that after performing the inverse logarithmic transformation, Global 1 models yield the following expressions for predicted quality and volume contracts for 1995:

$$\mathbf{PQUAL_i} = e^{-2.329} \bullet T_{i,95}^{\ 0.564} \bullet Q_{i,90}^{\ 0.166} \bullet Q_{i,91}^{\ 0.254}$$

$$\mathbf{PVOL_i} = e^{-1.971} \bullet T_{i,95}^{\ 0.524} \bullet V_{i,90}^{\ 0.115} \bullet V_{i,91}^{\ 0.341}$$

The next chapter discusses the output of the optimization model and provides analysis for the alignment of the Raleigh Battalion.

V. OPTIMIZATION MODEL IMPLEMENTATION

The optimization model for aligning the recruiting companies presented in Chapter III was implemented using the General Algebraic Modelling System (GAMS). [Ref. 7] The resulting integer program problem was solved by a commercially available solver called Zero/One Optimization Method (ZOOM) [Ref. 7, pp. 225-239] on a 80486-33 Mhz personal computer.

The author and a staff member from USAREC used the optimization model as implemented above to successfully align 24 of the recommended 36 battalions (the other 12 battalions need no realignment at this time). The average CPU time to align the companies in one battalion using the hardware described above is approximately 15 minutes.

To illustrate the model, it is assumed that the 36 battalions are aligned as proposed in Chapter II. Because of the variety of geographical features and county sizes, the Raleigh (North Carolina) Recruiting Battalion is selected for realignment. The GAMS model and necessary data files are located in Appendix F.

A. THE RALEIGH BATTALION

Below is a list of basic information on the battalion:

- The Raleigh Battalion contains all 100 counties located in North Carolina.
- The total projected target market population (17-21 years old) in 1995 is 510,640.

- There are seven candidate headquarters' locations in the following cities: Greenville, Raleigh, Fayetteville, Charlotte, Winston-Salem, Asheville and Burlington. All except Burlington currently contain a recruiting company headquarters. The headquarters in Burlington is added for demonstration purposes.

Below are descriptions of data and model parameters whose values are chosen based on experimentation and subjective judgement on the part of the author and USAREC staff members. If these values are deemed inappropriate, they can be easily changed and the model can be re-solved to obtain new solutions.

- The distances from the centroid of each county i to each company j ($D_{i,j}$) are straight line distances calculated from the longitude and latitude of the centroid of each county to those of the headquarters. (For this thesis, the commercial program called MAPINFO is used to obtain these distances.) These distances are then adjusted manually to account for difficult terrain on the road network. If the road network from some county i to headquarters j is judged to be too difficult or too lengthy, the distance from i to j is considered as infinity and the assignment of county i to headquarters j is not permitted in the model.

- In the objective function, the weight, V_i, for the distance from county i to its headquarters is set to $PQUAL_i/AVGQUAL$, where $PQUAL_i$ is the predicted number of quality contracts in county i and AVGQUAL is the average number of predicted quality contracts in a county (See Chapter IV).

- The second and third terms in the objective function are the penalties for deviation from the quality and volume goals. For the Raleigh Battalion, these penalties per unit deviation are:

$$PENQUAL = \frac{200 * 0.80}{QGOAL}$$

for quality, and

$$PENVOL = \frac{200 * 0.20}{VGOAL}$$

for volume. The goals for quality (QGOAL) and volume (VGOAL) contracts for each company are simply the average predicted 1995 quality and volume contracts per headquarters in the year 1995. The factor 200 is chosen to make the second and third terms in the objective functions comparable in magnitude with the other terms. The 0.80 and 0.20 terms are chosen to place appropriate emphasis on quality and volume respectively. Recent recruiting trends indicate that the Army is recruiting nearly 80% quality, and about 20% volume [Ref 9, p. 15].

- The maximum allowable deviation for both quality and volume is set between 20 and 25 percent of the respective goals.

- The costs associated with closing an existing company (PENCLOSE) is taken to be the penalty for breaking a lease and is provided by the Resource, Management and Logistic (RML) Division at USAREC. The cost of opening up a new company (i.e., the Burlington Company) is taken to be the average operating cost of the six existing companies in the battalion.

B. EXAMPLE OF GAMS OUTPUT

This section displays outputs for the Raleigh Battalion using the data stated in Section A with max deviation set to 20% and number of headquarters to be opened set to 5. As implemented, GAMS first produces the optimal county to company assignment as shown in Table 8. For example, the first row in the table shows that county 37001 is assigned to the Raleigh Recruiting Company and in the second row,

county 37003 . ,signed to the Winston-Salem Recruiting Company. Table 8 also shows the companies that remain open and they are: Fayetteville, Greenville, Raleigh, Winston-Salem, and Charlotte. Figure 6 graphically displays the information in Table 8.

TABLE 8 A COUNTY TO COMPANY ASSIGNMENT FOR THE RALEIGH BATTALION

COUNTY CODE	FAYETTEVILLE	GREENVILLE	RALEIGH	WINSTON SALEM	CHARLOTTE
37001	0	0	1	0	0
37003	0	0	0	1	0
37005	0	0	0	1	0
37007	0	0	0	0	1
37009	0	0	0	1	0
37011	0	0	0	1	0
37013	0	1	0	0	0
37015	0	1	0	0	0
37017	1	0	0	0	0
37019	1	0	0	0	0
37021	0	0	0	0	1
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
37199	0	0	0	1	0

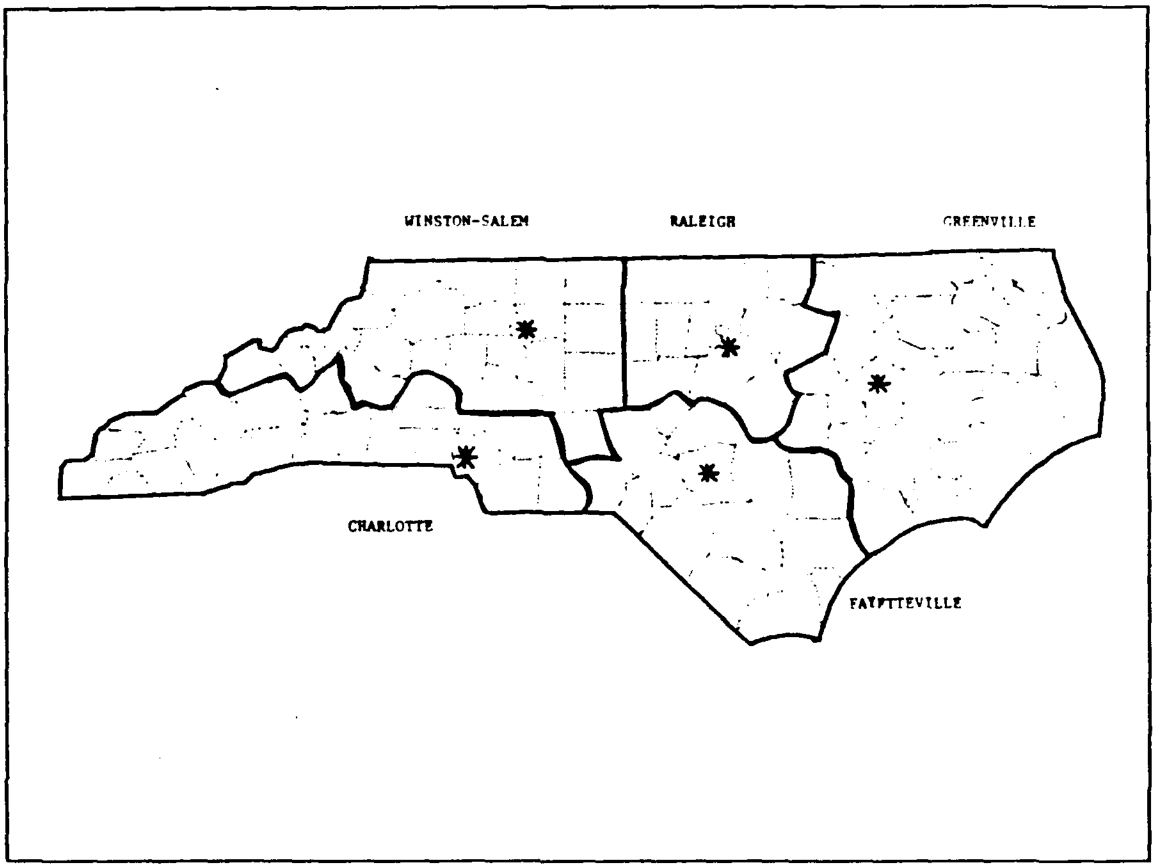


Figure 6 An Alignment of the Raleigh Battalion

Following the assignment report is the workload report, displayed in Table 9. The second column in this table shows the actual number of contracts predicted to be available in the territory of each company in 1995. The fourth column is the percent difference between the actual number of contracts and the goal. Recall that the goal is the total number of predicted contracts in the battalion divided by the number of companies opened (five in this Raleigh Battalion example). The fifth column shows the number of counties assigned to the company. Based on the assumption that each recruiter produces 18 contracts per year and the Army takes

40% of the contracts in the market, the last column provides the number of recruiters that should be assigned to each company.

TABLE 9 COMPANY WORKLOAD BASED ON QUALITY CONTRACTS FOR THE RALEIGH BATTALION

CITY	ACTUAL	GOAL	% DIFF	COUNTIES	NUMBER OF RECRUITERS
Fayetteville	1305	1401	-7.0	15	29
Greenville	1208	1401	-13.8	27	27
Raleigh	1227	1401	-12.5	13	27
Winston-Salem	1597	1401	13.9	23	35
Charlotte	1671	1401	19.2	22	37

C. *OUTPUT ANALYSIS*

To demonstrate possible applications of the company realignment model, the outputs obtained from varying model parameters are analyzed below.

1. Varying the number of company headquarters (NHQ):

To properly size the companies in the Raleigh Battalion, the number of headquarters, *NHQ*, was set at five, six, and seven with the deviation level from the contract goal set at 20%. Figure 7 displays the results when varying the recruiter quality contract mission to 12, 15, and 18 per year, while keeping the quality contract market share constant at 40% for the Army.

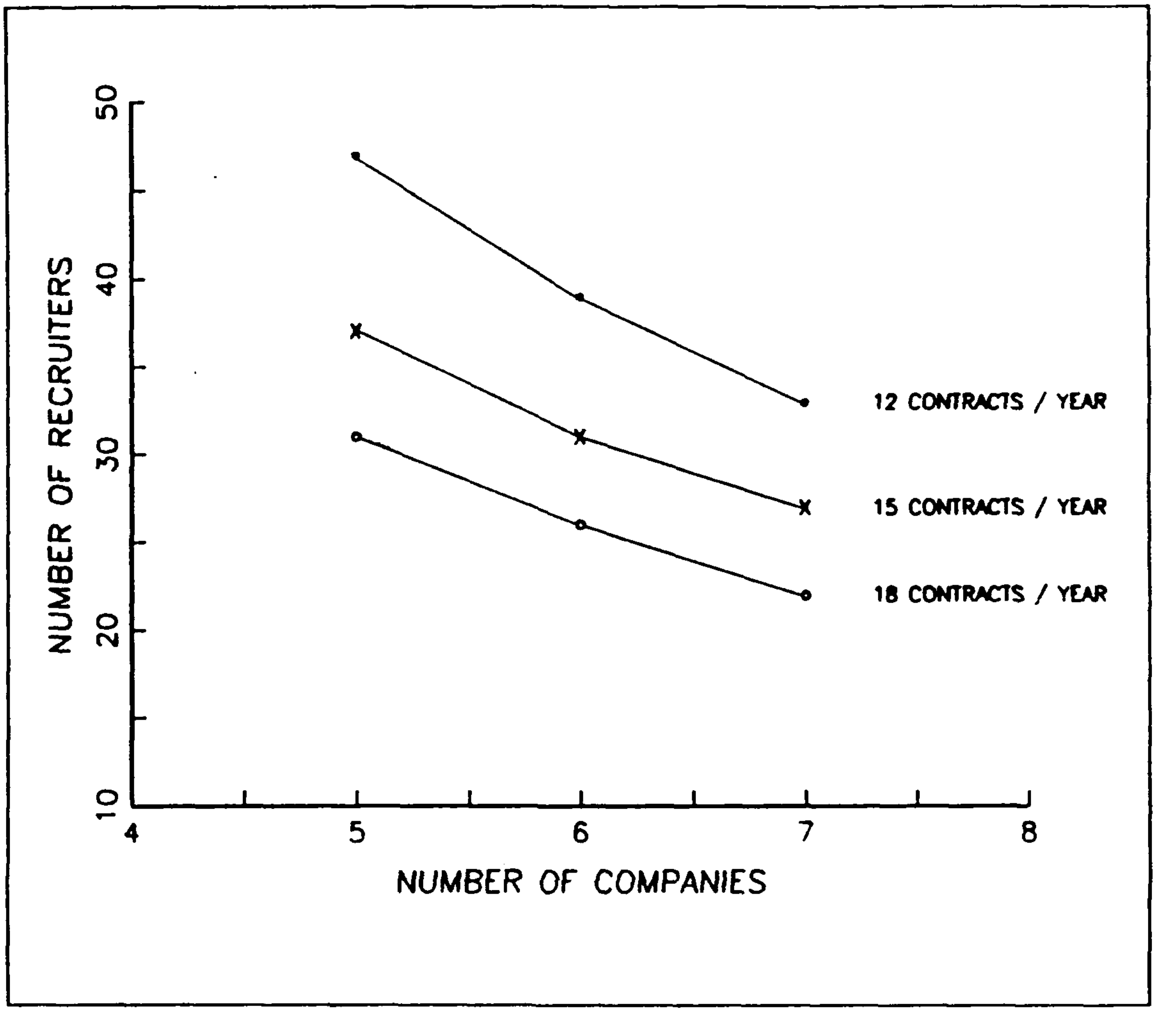


Figure 7 Number of Recruiters with Army taking 40% of contracts

Note that the five company configuration does not meet the USAREC guidance of having 20 active recruiters assigned per company [Ref. 2, p. 2] when the Army contract market share is assumed to be 40%. With each recruiter missioned at 18 contracts per year, all seven companies must be opened and each requires an average of 22 recruiters.

Figures 8 and 9 show the cases when the Army expects to take 35% and 30% of the quality contract market share respectively. At the 35% level (Figure 8), the USAREC recruiter guidance of 20 recruiters per company is still exceeded when the number of companies to be opened is five and six. However, with seven companies and 18 quality contracts per recruiter per year, the guidance of 20 recruiters per company is achieved.

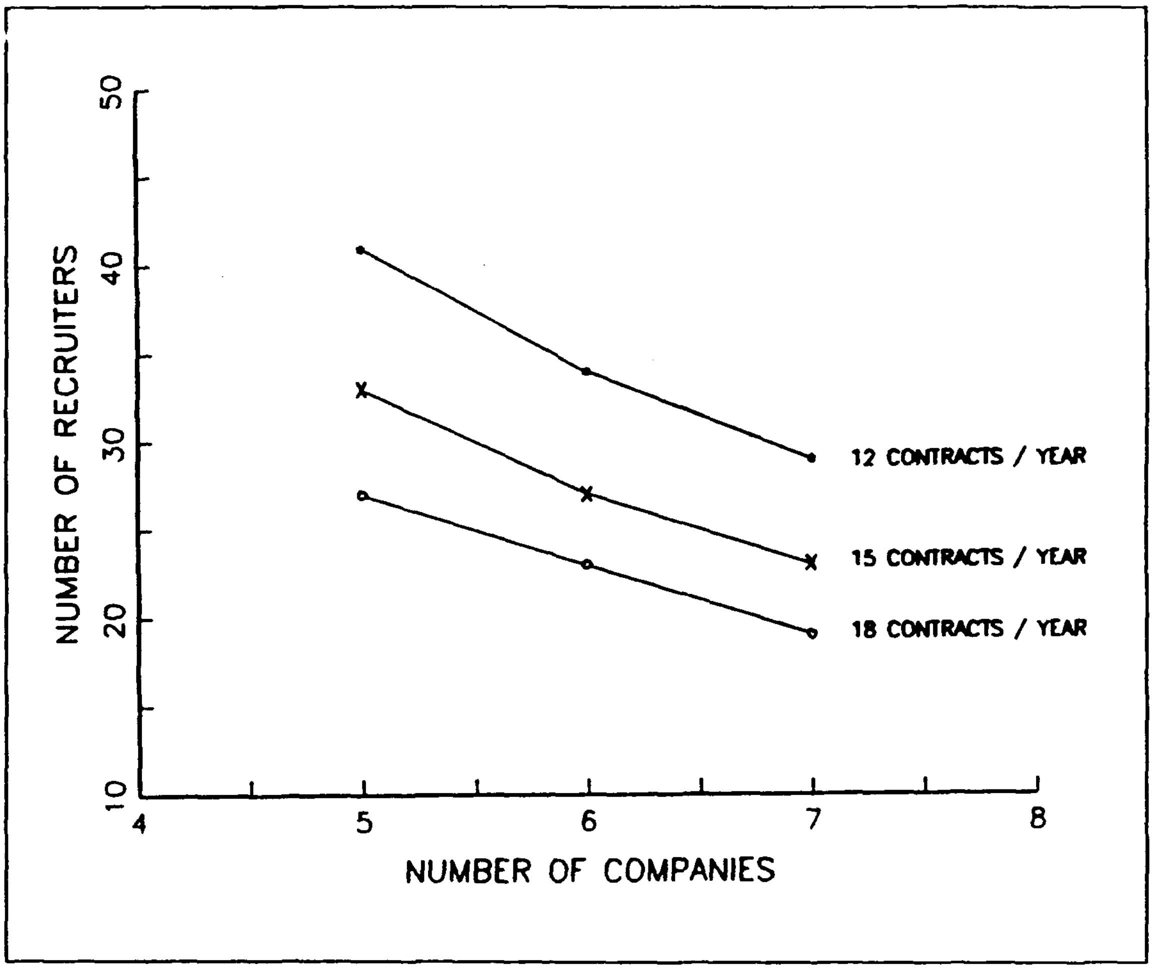


Figure 8 Number of Recruiters with Army taking 35% of contracts

Finally, assuming the Army market share is reduced to 30%, Figure 9 shows that the guidance is achieved using six companies with a mission of 18 contracts per recruiter per year. Alternatively, the guidance can also be achieved using seven companies with a mission of 15 *or* 18 contracts per year.

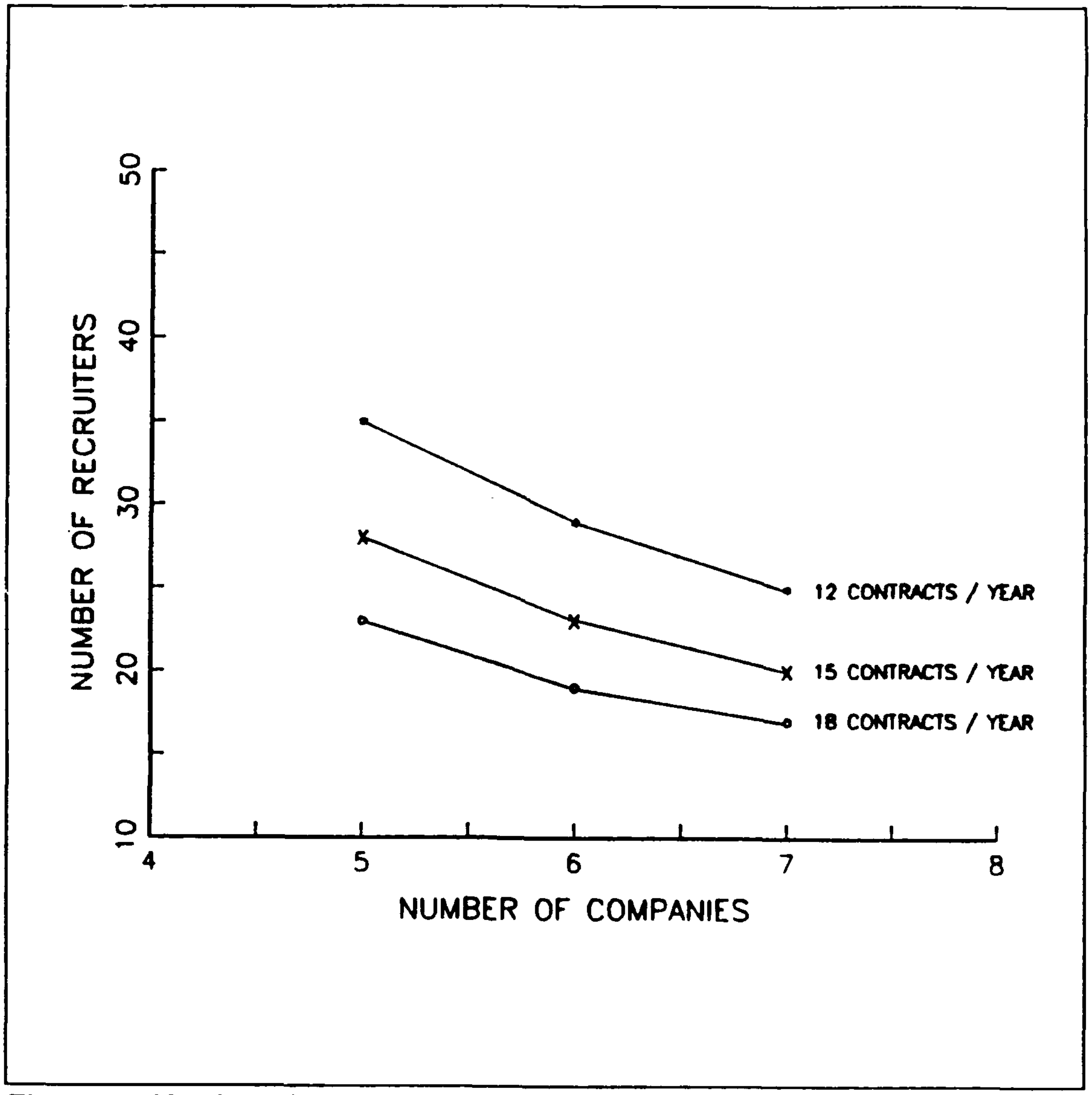


Figure 9 Number of Recruiters with Army taking 30% of contracts

2. Selecting the Maximum Allowable Deviation From the Goal

Ideally, the workload as measured in terms of quality and volume contracts should be the same for all companies in the same battalion. In practice, it may not be possible to achieve this equity in workload since a county can not be subdivided into small areas, with each one assigned to a different company. For administrative and other purposes, it is desirable to have an entire county be assigned to only one company. Therefore, small differences in workload among companies is acceptable and is accomplished in the model by selecting the appropriate value of maximum allowable deviation from the goal, i.e., the average number of quality and volume contracts. The main issue here is the appropriate value for maximum allowable deviation.

When this maximum allowable deviation is set too small, a county in the vicinity of a company headquarters may be assigned to another company headquarters which is much further away. This is due to the fact that the counties near a company may have small number of quality and volume contracts. So, to satisfy the maximum deviation requirement, a county further away, but having the appropriate number of quality and volume contracts, may be assigned to a distant company headquarters. This would create what is referred to as an "island" in the territory of a company (see Figure 10). However, an excessive maximum allowable deviation setting would allow large, perhaps unacceptable, amounts of variation in workload between companies.

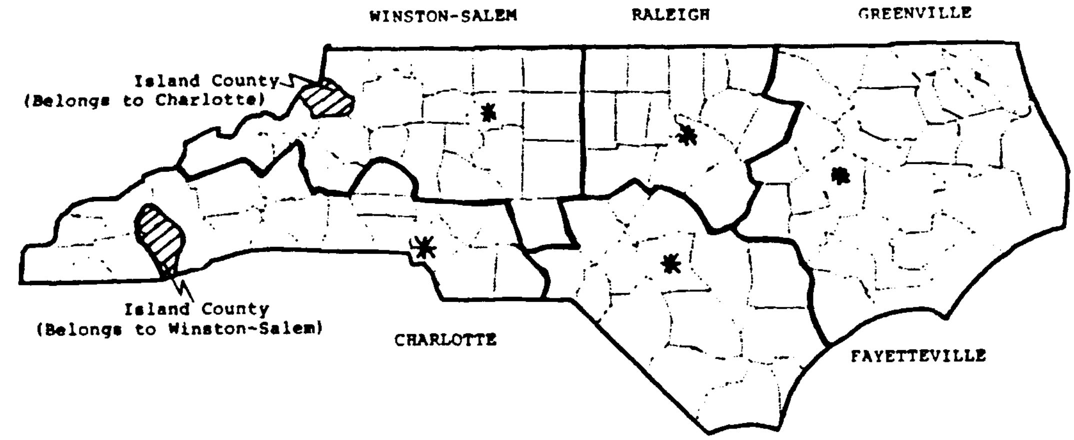


Figure 10 Illustration of an "Island"

Figure 11 displays the relationship between variation in workload and maximum allowable deviation where the variation in workload is defined as maximum {a,b}, and

$$a=\frac{(\text{max. } \mathit{quality\ contracts} - \text{min. } \mathit{quality\ contracts})}{\mathit{average\ contracts}}$$

$$b=\frac{(\text{max. } \mathit{volume\ contracts} - \text{min. } \mathit{volume\ contracts})}{\mathit{average\ contracts}}$$

It is interesting to note that the amount of variation levels off when maximum deviation reaches 0.25 for the Raleigh Battalion. Based on experience with other battalions, the variation seems to level off when maximum deviation is generally between 0.20 and 0.35. The maximum deviation at which the variation levels off is significant, for it is the value that prevents islands from appearing inside a company's territory.

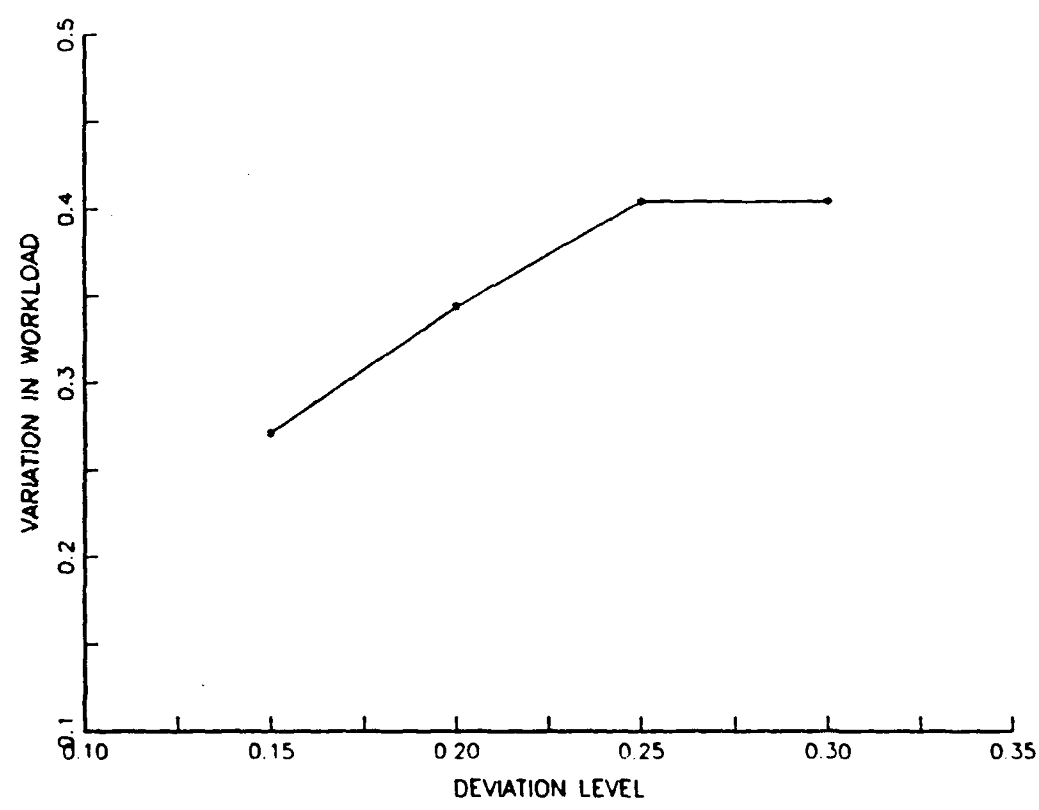


Figure 11 Amount of Variation in the Workload of a Company in the Raleigh Battalion

VI. CONCLUSION

The main objective of this thesis is to assist the U.S. Army Recruiting Command in its downsizing effort. In particular, two problems of immediate concern are considered; they are the realignment of recruiting battalions and companies. USAREC planners project that the number of recruiting battalions will be reduced from 47 to 36. To aid in the realignment of the remaining 36 battalions, this thesis identifies four realignment criteria:

- Proper trade-off between size and density.
- State ownership.
- Adequate command presence.
- Robustness with respect to shifts in population.

In addition, the thesis also proposes a realignment of the 36 battalions based on state boundaries and demonstrates that it satisfies all four criteria.

For the recruiting companies, this thesis provides an optimization model to assist the USAREC staff in realigning the companies within each of the 36 battalions. The optimization model is implemented in GAMS and can be applied to any of the battalions by supplying the appropriate data input. One important data requirement for the optimization model is a forecast of the number of prospective recruits referred to as *quality* and *volume contracts* earlier in this thesis. Two regression models were developed to predict the number of quality and volume contracts in

1995. Based on randomly selected data from 1990, 1986, and 1985, two models yield R^2 values of 0.9337 and 0.9487.

At the completion of the thesis, USAREC is considering the proposed realignment of the 36 battalions for implementation. For the company realignment, a staff member from USAREC has already used a prototype optimization model to develop realignment of 24 battalions. The remaining battalions are generally large metropolitan areas with small territory and require no realignment at this time. The implementation based on GAMS proved to be efficient. The realignment of the 24 battalions took approximately 1.5 days for data preparation and manipulation, and one half day for debugging and executing the program. Using a manual procedure, this realignment would have taken an analyst approximately two months to complete.

A. AREAS FOR FUTURE RESEARCH

Below is a list of areas for future research that can assist USAREC in downsizing its organization in the future.

1. **Realignment of Recruiting Stations**: The natural extension of this thesis is to realign the recruiting stations to support the realignment proposed above.

2. **Alternative forecasting models for recruiting markets**: Based on the 1990 data, unemployment and the average education level turned out to be statistically insignificant factors in predicting the number of quality and volume contracts. This is somewhat counter-intuitive and points out the necessity for further research in forecasting the recruiting markets which should include other predictive factors such as the level of recruiting efforts from other services, particularly the number of recruiters assigned to each county.

3. **Investigation of alternative objective function for the optimization model:** This thesis utilizes one objective function jointly developed by the author and staff members of USAREC. However, alternative objective functions exist and should be explored.

LIST OF APPENDICES

APPENDIX A

BATTALION POPULATION PROJECTIONS

BATTALION	STATES	1995 POPULATION 17-21 YRS OLD	AREA (SQ MILES)	POPULATION DENSITY
Brunswick	Maine	88,660	30,995	
	New Hampshire	93,330	8,992	
	Eastern Mass	282,982	3,842	
	TOTAL:	464,972	43,829	10.61
Springfield	Vermont	44,787	9,273	
	Connecticut	214,048	4,872	
	Rhode Island	70,957	1,054	
	Western Mass	107,886	4,434	
	TOTAL:	437,678	19,633	22.29
New York	8 Counties	661,565	2,308	286.64
(Counties: Suffolk, Nassau, Kings, Queens, Richmond, Bronx, Westchester, New York (Manhattan))				
Syracuse	Rest of NY	520,185	45,071	11.54
Phila-delphia	New Jersey	510,487	7,468	
	SE PA (5 Counties)	245,880	2,211	
	TOTAL:	756,367	9,679	78.15
Pittsburgh	Rest of PA	554,936	42,681	13.00
Baltimore	Maryland	328,618	9,838	
	Delaware	51,292	1,933	
	Wash D.C.	41,631	63	
	TOTAL:	421,541	11,834	35.62
Beckley	Virginia	462,486	39,700	
	West Virginia	133,208	24,124	
	TOTAL:	595,694	63,824	9.33

BATTALION	STATES	1995 POPULATION 17-21 YRS OLD	AREA (SQ MILES)	POPULATION DENSITY
Raleigh	N. Carolina	510,640	48,843	10.45
Columbia	S. Carolina	288,060	30,207	9.54
Atlanta	Georgia	521,392	58,060	8.98
Miami	SE Florida	425,142	15,649	27.17
Tampa	W/N Florida	488,465	38,508	12.68
Jackson	Mississippi	216,612	47,234	
	Alabama	314,937	50,776	
	TOTAL:	531,549	98,010	5.42
New Orleans	Louisiana	356,120	44,520	
	Arkansas	181,040	52,080	
	TOTAL:	537,160	96,600	5.56
Nashville	Kentucky	284,810	39,674	
	Tennessee	362,677	41,154	
	TOTAL:	647,487	80,828	8.01
Kansas City	Kansas	185,365	81,783	
	Missouri	373,653	68,945	
	TOTAL:	559,018	150,728	3.71
Des Moines	Iowa	206,389	55,965	
	Nebraska	121,621	76,639	
	South Dakota	54,695	75,956	
	TOTAL:	382,705	208,560	1.83
Minneapolis	Minnesota	318,036	79,548	
	North Dakota	54,429	69,299	
	TOTAL:	372,465	148,847	2.50
Chicago	Illinois	815,842	55,646	14.66
Milwaukee	Wisconsin	352,841	54,424	
	Mich U.P.	18,538	12,013	
	TOTAL:	371,379	66,437	5.59
Lansing	Rest of Mich	655,928	44,946	14.59

BATTALION	STATES	1995 POPULATION 17-21 YRS OLD	AREA (SQ MILES)	POPULATION DENSITY
India-napolis	Indiana	416,779	35,936	11.60
Cleveland	North Ohio	415,104	19,121	21.70
Columbus	South Ohio	341,770	34,577	9.88
Seattle	Washington	360,124	66,512	
	Oregon	212,190	96,187	
	TOTAL:	572,314	162,699	3.52
Los Angeles	4 Counties	707,043	12,028	58.78
(Counties: Los Angeles, Ventura, Santa Barbara, San Luis Obispo)				
Santa Ana	12 Counties	698,720	68,881	10.14
(Counties: San Diego, Imperial, Orange, Riverside, Kern, San Bernadino, Kings, Tulare, Inyo, Madera, Mono, Merced)				
Sacramento	Northern CA	766,082	75,388	10.16
Phoenix	Arizona	290,625	113,510	
	New Mexico	127,900	121,336	
	TOTAL:	418,525	234,846	1.78
Salt Lake City	Utah	162,363	82,076	
	Idaho	92,415	82,413	
	Nevada	79,759	109,895	
	TOTAL:	334,537	274,384	1.22
Denver	Colorado	266,633	103,598	
	Wyoming	36,358	96,988	
	Montana	60,711	145,388	
	TOTAL:	363,702	345,974	1.05
Oklahoma City	Oklahoma	250,187	68,656	
	TX Panhandle	77,514	49,070	
	TOTAL:	327,701	117,726	2.78
Dallas	NE Texas	397,405	42,001	9.46

BATTALION	STATES	1995 POPULATION 17-21 YRS OLD	AREA (SQ MILES)	POPULATION DENSITY
Houston	SE Texas	511,260	54,915	9.31
San Antonio	West Texas	436,491	141,314	3.09

APPENDIX B
SUMMARY OF COUNTIES USED FOR THE REGRESSION MODEL

STATE NAME	STATE CODE	COUNTIES: TOTAL IN STATE	COUNTIES: NUMBER USED IN MODEL	COUNTIES: PERCENT OF TOTAL	SIGNIFICANT COUNTIES/CITIES
ALAB	1	67	6	9.0	
ARIZ	4	14	2	14.3	
ARK	5	75	6	8.0	
CAL	6	58	6	10.3	SAN FRANCISCO STANISLAUS/ MODESTO
COLO	8	63	12	19.0	JEFFERSON/ W.DENVER LARIMER/FORT COLLINS
CONN	9	8	1	12.5	
DEL	10	3	1	33.3	
FLA	12	67	6	9.0	DUVALL/ JACKSONVILLE
GEO	13	159	14	8.8	RICHMOND/ AUGUSTA
IDA	16	44	2	4.5	
ILL	17	102	10	9.8	KANE/CHICAGO SUBURBS
IND	18	92	7	7.6	ST JOSEPH/SOUTH BEND
IOWA	19	99	5	5.1	
KS	20	105	14	13.3	DOUGLAS/LAWRENCE RILEY/FORT RILEY
KY	21	120	14	11.7	
LA	22	64	6	9.4	JEFFERSON/NEW ORLEANS

STATE NAME	CODE	COUNTIES TOTAL IN STATE	NUMBER USED IN MODEL	PERCENT OF TOTAL	SIGNIFICANT COUNTIES/CITIES
MAINE	23	16	1	6.3	
MD	24	24	1	4.2	
MASS	25	14	2	14.3	HAMPDEN/ SPRINGFIELD SUFFOLK/BOSTON
MICH	26	83	12	14.5	KENT/GRAND RAPIDS ST. CLAIR/PORT HURON
MINN	27	87	3	3.4	
MISS	28	82	10	12.2	RANKIN/JACKSON SUBURBS
MO	29	116	15	12.9	GREENE/ SPRINGFIELD
MONT	30	57	5	8.8	LEWIS & CLARK/ HELENA
NEB	31	93	17	18.3	
NEV	32	17	0	0.0	
NH	33	20	2	10.0	MERRIMACK/ CONCORD
NJ	34	21	0	0.0	
NM	35	31	4	12.9	
NY	36	62	5	8.1	QUEENS
NC	37	100	11	11.0	N. HANOVER/ WILMINGTON
ND	38	53	6	11.3	

STATE NAME	STATE CODE	COUNTIES TOTAL IN STATE	COUNTIES NUMBER USED IN MODEL	COUNTIES PERCENT OF TOTAL	SIGNIFICANT COUNTIES/CITIES
OH	39	88	13	14.8	CUYAHOGA/ CLEVELAND FRANKLIN/ COLUMBUS LORAIN/ W.CLEVELAND LUCAS/TOLEDO PORTAGE/KENT
OK	40	77	6	7.8	PAYNE/ STILLWATER
OR	41	36	1	2.8	
PA	42	67	7	10.4	ERIE/ERIE PHILADELPHIA
RI	44	5	0	0.0	
SC	45	46	2	4.4	
SD	46	69	5	7.2	BROWN/ABERDEEN
TENN	47	95	11	11.6	
TEX	48	254	31	12.2	KILEEN/FT. HOOD BEXAR/SAN ANTONIO DALLAS
UTAH	49	49	4	13.8	
VER	50	14	1	7.2	WASHINGTON/ MONTPELIER
VA	51	100	8	8.0	PRINCE WILLIAM/ QUANTICO
WASH	53	44	7	15.9	GRAYS HARBOR/ ABERDEEN WHITMAN/PULLMAN

STATE NAME	CODE	COUNTIES TOTAL IN STATE	NUMBER USED IN MODEL	PERCENT OF TOTAL	SIGNIFICANT COUNTIES/CITIES
WV	54	55	8	14.5	
WIS	55	71	5	7.0	
WYO	56	23	5	21.7	SHERIDAN/ SHERIDAN

APPENDIX C

COUNTY LEVEL DATA

CNTY	$Q_{i,90}$	$V_{i,90}$	$T_{i,90}$	$U_{i,90}$	$M_{i,90}$	$E_{i,90}$	$Q_{i,85}$	$V_{i,85}$	$Q_{i,86}$	$V_{i,86}$
1023	10	20	1398	0.114	22363	9.71	20	36	9	30
1027	13	24	1053	0.062	23749	10.13	8	20	8	26
1045	85	135	4063	0.074	25402	11.5	77	128	110	177
1079	25	54	2644	0.097	24966	9.74	20	46	17	37
1087	33	72	2426	0.078	18744	10.9	21	63	36	92
1093	32	57	2469	0.123	22648	9.73	21	34	54	84
4003	181	243	7985	0.066	24743	11.75	172	266	202	306
4023	20	39	2038	0.146	26159	10.54	15	31	17	37
5023	28	43	1386	0.075	21323	10.1	20	33	36	53
5043	35	52	1452	0.087	22701	10.62	21	46	26	50
5067	20	47	1418	0.115	18857	9.52	14	31	28	83
5081	26	36	1185	0.055	23668	10.25	10	22	17	31
5091	56	86	2940	0.063	25006	10.64	33	81	41	72
5113	23	33	1316	0.057	21314	10.08	24	43	37	60
6015	39	48	1346	0.126	23949	11.67	28	41	25	37
6039	105	167	6647	0.123	26077	11.01	66	121	73	133
6057	63	83	5278	0.055	30237	12.99	54	85	89	121
6069	33	45	3093	0.125	30060	10.73	22	31	20	36
6075	284	484	36213	0.040	35522	12.73	404	757	420	808
6099	331	519	27257	0.113	27311	11.33	287	457	318	500
8023	2	6	237	0.111	19412	9.81	8	16	5	12
8025	5	9	229	0.037	18558	10.48	7	14	5	8
8053	1	1	17	0.022	33714	13.8	0	0	1	1
8057	4	4	100	0.041	33652	12.2	0	4	5	5
8059	581	748	33471	0.040	47155	13.61	499	724	687	920
8069	266	326	17015	0.044	35069	13.35	265	360	263	342
8093	10	18	436	0.063	32453	13.11	12	20	13	15
8099	20	25	1083	0.053	29738	11.45	10	13	19	32
8105	18	29	873	0.093	25066	11.17	16	25	18	31
8109	5	8	268	0.155	18491	10.54	4	7	5	9
8121	5	10	354	0.032	31400	11.27	2	4	7	8
8125	7	8	668	0.027	25134	11.35	7	12	12	17
9015	150	238	7831	0.074	35918	11.05	171	269	176	256
10005	94	167	8560	0.049	29937	10.93	130	245	145	232
12031	889	1277	52741	0.056	30128	11.85	820	1467	944	1667
12039	55	107	3824	0.059	23066	9.2	33	93	63	132
12059	43	50	1417	0.072	20996	9.49	21	31	35	48
12065	13	25	990	0.051	20386	10.36	11	30	22	40
12069	168	218	9175	0.079	25264	11.3	171	266	184	270
12089	51	68	4005	0.058	33187	11.07	40	82	67	108
13037	8	21	436	0.056	24890	8.99	11	28	11	29
13057	82	106	6708	0.044	38660	10.6	45	59	54	86
13125	4	7	154	0.055	23497	8.75	3	4	2	7
13173	9	13	470	0.048	19423	9.53	9	18	7	15
13189	13	29	1608	0.051	24685	9.81	12	38	19	44

CNTY	$Q_{i,90}$	$V_{i,90}$	$T_{i,90}$	$U_{i,90}$	$M_{i,90}$	$E_{i,90}$	$Q_{i,85}$	$V_{i,85}$	$Q_{i,86}$	$V_{i,86}$
13201	12	18	575	0.044	21345	9.77	5	7	7	11
13233	37	61	2718	0.116	26430	9.48	32	65	42	90
13235	10	14	714	0.053	25646	10.02	10	26	6	22
13239	1	2	178	0.105	19601	8.68	1	4	1	1
13241	10	15	866	0.049	25098	10.42	6	8	6	12
13245	242	398	15524	0.051	29342	11.42	195	366	221	425
13249	1	5	317	0.091	24931	9.95	8	11	5	8
13275	61	98	3223	0.055	25138	10.35	27	79	47	90
13313	53	67	5962	0.049	33004	10	59	94	74	119
16051	19	28	1357	0.066	24713	11.99	26	38	22	39
16075	23	41	1265	0.069	21955	11.18	43	70	43	69
17005	9	12	1188	0.083	26485	10.47	20	29	25	34
17021	45	70	2433	0.063	28819	10.95	55	80	58	94
17023	17	26	1069	0.099	24510	10.62	20	40	27	41
17033	22	31	1360	0.104	29053	11.09	32	52	29	46
17047	12	14	532	0.079	26932	10.73	9	16	16	24
17063	47	59	2386	0.085	37309	11.47	31	57	39	52
17089	289	415	24748	0.059	39754	12.08	291	451	308	450
17103	54	72	2415	0.063	35020	11.56	68	105	72	101
17109	55	75	5429	0.052	27429	12.44	50	74	50	82
17167	214	304	11979	0.044	36728	12.25	194	318	231	368
18025	8	15	780	0.079	23771	9.72	10	23	15	28
18027	30	45	2031	0.047	24872	10.84	30	47	46	74
18041	43	67	2059	0.120	28586	10.79	47	90	64	92
18123	41	54	1337	0.097	27338	10.16	27	40	34	50
18141	270	402	22126	0.054	33970	11.93	261	448	299	453
18151	19	30	2153	0.045	31937	11.98	28	39	32	39
18183	30	45	2116	0.058	32664	11.77	32	51	33	45
19001	6	7	543	0.031	24449	11.29	15	20	21	27
19011	29	34	1546	0.059	29727	11.31	36	62	39	61
19045	84	115	3908	0.066	34570	11.68	105	150	164	218
19165	18	23	1014	0.044	27126	11.29	25	35	35	40
19181	36	49	3153	0.027	34187	12.25	59	83	68	88
20005	23	31	1407	0.057	25606	11.63	21	37	31	46
20007	8	11	354	0.033	27457	11.75	4	5	8	9
20041	25	36	1338	0.044	27732	11.5	12	20	20	31
20043	14	22	690	0.057	27158	10.8	5	16	11	20
20045	96	121	9330	0.036	31339	13.6	88	126	109	149
20047	6	10	213	0.031	29885	11.85	4	6	3	5
20053	2	4	350	0.030	24279	11.36	3	3	9	13
20067	5	8	487	0.027	32407	11.82	7	8	8	13
20121	40	54	1743	0.052	29418	11.49	27	39	39	58
20135	9	11	214	0.025	31319	11.47	3	4	2	3
20139	29	44	1120	0.067	28643	11.56	8	22	26	40
20161	70	96	9947	0.037	28608	13.62	43	75	70	94
20169	68	107	3525	0.042	31807	12.32	87	121	88	130
20197	10	11	428	0.044	22857	11.83	5	9	11	19
21001	14	19	1187	0.064	22225	8.72	11	17	15	26
21049	36	55	2219	0.067	13973	7.86	49	72	33	53

CNTY	$Q_{i,90}$	$V_{i,90}$	$T_{i,90}$	$U_{i,90}$	$M_{i,90}$	$E_{i,90}$	$Q_{i,85}$	$V_{i,85}$	$Q_{i,86}$	$V_{i,86}$
21071	40	56	3849	0.069	32090	11.48	25	46	40	67
21075	9	14	533	0.086	27045	9.55	9	15	7	21
21083	42	59	2197	0.093	21282	8.65	28	58	37	55
21089	43	77	2814	0.060	27881	10.4	50	95	63	103
21131	8	19	1192	0.057	21134	8.87	4	18	13	27
21137	15	29	1413	0.085	24014	9.96	17	27	20	39
21145	75	113	4114	0.051	13376	8.02	76	129	84	126
21155	10	19	1315	0.082	26198	10.51	18	25	21	35
21165	3	4	430	0.109	26765	10.28	3	8	10	15
21169	3	11	810	0.059	19252	8.08	7	15	6	11
21203	9	20	1218	0.070	22018	10.32	10	23	13	24
21205	26	38	1985	0.059	18452	8.73	14	32	27	47
22011	57	73	2627	0.064	22670	10.13	48	79	64	92
22047	29	50	2668	0.089	22526	10.39	24	50	29	77
22051	488	716	35688	0.052	28473	10.04	404	695	494	796
22053	49	76	2612	0.076	31987	11.68	19	44	49	84
22069	48	81	3393	0.070	23133	11.3	44	75	47	84
22091	5	16	894	0.088	31026	10.19	7	11	13	24
23015	33	40	2058	0.032	25689	11.62	40	55	43	55
24001	106	163	5997	0.088	46845	12.23	111	206	91	172
25013	460	751	32931	0.060	37477	12.65	429	756	468	831
25025	324	634	50637	0.057	39492	11.78	379	777	424	907
26003	26	38	610	0.078	31248	11.41	15	23	17	26
26005	81	114	7074	0.057	25841	11.18	96	157	86	135
26007	39	61	2384	0.103	23657	11.76	62	86	56	92
26019	15	19	827	0.127	29574	11.54	17	29	19	33
26061	42	54	4072	0.069	27095	10.45	58	84	59	84
26069	48	65	2170	0.086	22919	11.2	59	90	58	83
26081	422	581	36933	0.061	17007	9.93	416	638	455	673
26083	1	2	98	0.132	17853	10.42	3	4	6	7
26091	101	147	7276	0.080	42899	12.61	126	197	152	207
26129	34	49	1407	0.103	26054	11.17	26	38	27	37
26147	178	255	11776	0.093	29615	11.53	180	293	189	289
26165	35	57	2019	0.112	22583	10.79	48	72	36	75
27033	11	20	929	0.064	26454	11.27	12	14	17	29
27047	25	36	2411	0.107	33325	11.25	49	76	79	110
27049	57	75	2878	0.040	25274	10.43	60	92	91	122
28007	19	40	1504	0.104	20576	9.13	14	35	28	48
28037	6	14	620	0.076	23798	10.56	7	13	6	13
28039	21	35	1435	0.127	20286	10.36	18	29	20	46
28053	7	24	1135	0.087	19746	8.34	10	25	9	27
28085	30	58	2586	0.076	24578	10.96	16	35	20	55
28103	21	32	981	0.128	23014	12.04	14	34	15	33
28121	95	142	7178	0.043	21168	10	64	103	70	141
28123	32	57	2135	0.059	15309	9.49	11	15	21	45
28127	23	59	1903	0.064	21325	10.41	13	29	18	47
28151	83	156	5845	0.107	20493	10.12	45	118	80	174
29031	72	94	4672	0.044	22520	10.59	87	130	99	154
29065	27	33	1056	0.065	19284	9.79	25	44	27	37

CNTY	$Q_{i,90}$	$V_{i,90}$	$T_{i,90}$	$U_{i,90}$	$M_{i,90}$	$E_{i,90}$	$Q_{i,85}$	$V_{i,85}$	$Q_{i,86}$	$V_{i,86}$
29077	305	392	18105	0.043	22659	11.12	227	323	313	427
29087	6	11	381	0.061	26442	10.59	8	13	8	13
29091	50	71	2357	0.068	21609	9.74	33	61	56	86
29099	228	321	14212	0.079	26540	12.15	216	363	293	422
29103	6	7	361	0.060	23619	10.39	3	8	5	6
29115	10	17	896	0.080	23212	11.03	14	23	24	40
29149	14	19	668	0.068	30068	9.48	9	19	22	32
29155	30	56	1759	0.086	26167	9.09	32	60	35	83
29159	45	58	2611	0.069	28806	11.11	50	73	61	100
29167	27	39	1875	0.049	23934	11.42	29	40	37	54
29197	4	8	314	0.048	22665	10.57	7	11	5	11
29227	2	2	152	0.048	21923	10.88	5	5	1	1
29229	26	31	1239	0.090	18751	9.65	31	50	25	39
30001	13	13	587	0.043	24136	12.57	13	17	19	25
30049	150	186	3596	0.045	30462	13.06	117	158	137	177
30053	34	64	1396	0.115	28010	11.83	31	42	40	58
30079	2	2	109	0.049	19175	10.71	1	6	6	7
30097	6	7	224	0.031	21406	11.61	9	9	3	8
31027	14	17	742	0.018	23698	10.67	14	21	25	31
31031	5	6	436	0.019	23658	12.1	4	9	14	18
31035	4	5	528	0.020	29685	11.5	10	16	15	16
31041	13	19	871	0.016	25853	11.64	8	11	11	19
31049	3	3	147	0.027	26226	11.81	3	3	6	8
31057	3	3	149	0.009	26952	10.84	2	5	3	5
31063	6	6	242	0.012	27500	11.88	1	1	2	3
31075	4	4	58	0.009	25957	12.33	3	5	0	1
31081	19	23	626	0.017	28162	11.96	9	12	12	16
31101	12	20	629	0.027	29809	11.99	16	17	19	25
31103	0	1	70	0.020	23804	11.18	0	0	0	0
31107	17	23	680	0.023	22738	10.65	16	21	18	28
31135	0	2	224	0.013	31862	11.79	3	5	2	4
31141	46	62	2322	0.021	29574	11.8	35	49	54	69
31173	8	15	563	0.051	21473	10.82	10	16	5	14
31177	23	34	1337	0.022	33616	11.94	21	31	24	32
31181	8	10	288	0.014	28296	11.39	3	7	3	4
33013	175	225	9248	0.052	37610	12.44	10	16	99	166
33019	59	80	2949	0.057	30050	11.49	16	22	63	78
35003	2	6	213	0.134	17275	11.57	2	4	5	8
35041	23	31	1268	0.040	21778	11.7	26	35	34	51
35051	15	20	576	0.053	17002	10.53	8	20	10	18
35057	14	24	816	0.080	18607	10.73	10	17	15	27
36043	88	124	4980	0.056	27922	11.42	97	156	119	167
36069	130	179	7563	0.044	37298	12.08	137	196	157	226
36077	70	93	6652	0.040	28852	11.96	92	143	101	156
36081	1057	1738	115199	0.060	34915	11.45	1096	2105	1297	2379
36085	165	259	29467	0.064	45921	11.9	200	341	195	361
37013	49	89	2997	0.054	24545	10.69	35	77	43	102
37039	25	32	1667	0.088	21791	9.61	13	20	15	23
37053	15	17	1085	0.024	25101	10.79	17	27	14	26
37075	3	6	528	0.191	21944	9.51	5	9	5	8

CNTY	$Q_{i,90}$	$V_{i,90}$	$T_{i,90}$	$U_{i,90}$	$M_{i,90}$	$E_{i,90}$	$Q_{i,85}$	$V_{i,85}$	$Q_{i,86}$	$V_{i,86}$
37079	11	31	1244	0.035	23240	9.72	13	34	10	29
37087	58	80	3550	0.052	27511	10.58	75	111	84	115
37123	27	56	1867	0.059	26893	9.87	11	28	12	29
37129	160	220	9620	0.042	32641	11.86	119	222	133	220
37139	39	56	2468	0.042	24046	10.65	29	56	26	52
37169	20	35	2952	0.044	30860	9.91	10	24	20	28
37185	16	42	1197	0.053	22426	9.48	8	22	25	62
38007	0	1	87	0.031	33019	10.87	0	1	1	1
38019	8	10	416	0.052	26905	10.88	7	8	11	15
38033	3	4	137	0.022	28590	11.83	2	2	10	12
38045	2	5	424	0.033	21216	10.37	6	8	12	16
38059	43	52	1805	0.047	28147	10.47	44	56	79	100
38105	36	44	1689	0.038	31334	11.84	19	27	69	84
39029	132	206	7808	0.059	31248	11.27	187	340	201	324
39033	68	103	3615	0.105	27349	11.38	83	138	99	162
39035	1159	1844	94634	0.048	35243	11.95	1572	2719	1663	2766
39045	155	208	8168	0.061	35040	11.64	149	251	181	265
39049	945	1397	76693	0.039	35861	12.56	1213	1879	1291	2013
39053	26	51	2294	0.077	26126	10.54	44	91	56	86
39055	78	108	6385	0.040	43391	12.67	101	135	103	129
39057	156	207	11543	0.047	38044	12.57	211	329	250	356
39065	29	40	2969	0.078	27607	11.46	32	60	43	67
39093	392	563	22020	0.077	33891	11.73	486	763	500	780
39095	586	876	34921	0.073	33394	11.83	559	954	580	963
39111	15	23	1156	0.108	27991	10.68	19	38	28	54
39133	144	209	13663	0.053	33746	12.15	187	295	197	308
40011	17	30	909	0.046	27037	11.09	7	18	11	25
40061	9	19	860	0.120	18716	9.85	7	14	19	33
40065	62	95	2299	0.069	23120	11.7	41	58	35	53
40075	10	17	778	0.039	21333	10.57	9	14	10	16
40107	15	36	908	0.052	18753	9.92	12	14	8	14
40119	72	91	9793	0.046	27855	12.71	46	86	85	127
41007	32	51	2211	0.064	28067	12.28	36	61	56	79
42005	81	118	5695	0.081	28836	10.56	120	197	130	215
42049	420	612	21739	0.055	30570	11.92	424	675	505	755
42051	174	295	11011	0.079	25803	10.53	217	437	232	411
42059	65	98	2964	0.091	27288	10.42	56	105	67	110
42081	155	230	8623	0.072	28996	11.52	234	384	219	351
42101	1054	1953	115367	0.060	26427	10.94	1373	2945	1604	3413
42115	79	110	3093	0.078	27011	11.52	78	110	76	106
45017	13	25	939	0.073	23673	10.03	8	23	12	36
45025	51	98	3033	0.047	25894	9.59	23	50	38	86
46013	73	87	2697	0.049	27212	11.77	61	96	85	116
46061	2	2	264	0.032	17083	10.17	4	7	2	3
46063	1	1	125	0.028	21667	11.2	2	3	3	3
46095	4	8	179	0.052	16157	10.32	2	7	4	7
46117	7	8	181	0.042	25546	11.61	1	2	5	7
47023	9	14	1087	0.053	26935	9.64	8	19	21	43
47045	41	55	2596	0.053	24645	9.54	26	56	42	67
47049	22	35	1318	0.093	16290	8.26	16	23	13	24

CNTY	$Q_{i,90}$	$V_{i,90}$	$T_{i,90}$	$U_{i,90}$	$M_{i,90}$	$E_{i,90}$	$Q_{i,85}$	$V_{i,85}$	$Q_{i,86}$	$V_{i,86}$
47051	46	59	3009	0.049	26940	10.29	26	59	40	70
47061	15	23	1193	0.091	20411	8.54	9	18	4	14
47083	7	12	573	0.104	24339	9.81	4	8	7	13
47101	11	13	813	0.080	20516	9.8	7	11	11	23
47111	18	22	1090	0.073	24810	8.38	7	11	6	14
47121	7	9	690	0.094	23963	9.61	2	11	9	17
47145	65	90	3876	0.068	27536	10.34	81	116	77	134
47181	10	16	1076	0.067	22286	8.81	5	10	15	29
48007	29	39	1263	0.044	24314	11.15	19	25	27	40
48009	9	10	571	0.039	28499	11.49	4	7	7	11
48021	74	96	2996	0.048	24757	10.31	25	51	33	59
48027	316	512	16169	0.067	25570	11.94	207	338	307	561
48029	2001	3054	99451	0.071	29754	11.4	1263	2428	1793	3063
48031	6	10	466	0.025	21539	10.87	1	2	6	9
48037	127	199	5916	0.064	28504	11.26	87	175	103	199
48045	2	3	161	0.024	21707	10.67	1	1	2	3
48071	20	26	1517	0.046	36652	11.08	9	23	19	37
48077	15	16	664	0.039	29596	10.63	3	7	6	10
48081	3	8	206	0.018	30818	10.91	1	3	7	8
48107	4	9	634	0.047	21154	9.58	5	13	11	24
48113	1659	2531	140102	0.053	37208	12.49	1392	2404	1849	2947
48159	10	15	501	0.049	29450	10.7	6	11	12	17
48163	13	21	1200	0.069	18251	9.25	6	17	11	30
48165	19	21	1183	0.048	27063	10.52	6	7	13	20
48169	5	12	389	0.050	25110	9.91	5	7	7	17
48223	31	45	2196	0.059	25780	10.98	17	38	29	56
48235	2	4	171	0.031	27832	11.3	1	2	5	7
48361	131	179	6478	0.088	37733	11.41	115	183	135	223
48371	20	31	1350	0.061	25364	10.14	15	20	21	44
48373	36	55	2215	0.068	21713	10.22	26	38	41	65
48381	131	165	7483	0.039	37245	13.32	122	159	140	200
48405	12	17	647	0.049	22115	9.6	15	31	10	21
48417	2	4	222	0.030	30559	10.89	3	6	7	9
48445	17	32	1081	0.061	25277	10.17	9	21	12	21
48453	641	901	48324	0.046	38549	12.97	490	750	720	1063
48473	24	38	2936	0.050	30782	11.38	13	27	20	42
48479	91	159	12611	0.108	18423	9.16	51	132	63	135
48481	29	53	3001	0.043	30902	10.13	33	60	47	92
48489	17	36	1783	0.152	19095	8.33	11	30	5	25
49015	11	19	885	0.079	32904	12.42	15	24	10	16
49017	7	10	316	0.104	21831	12.44	3	6	3	3
49025	6	7	363	0.060	24784	12.92	4	6	4	5
49041	22	33	1141	0.055	27320	12.68	10	18	18	34
50023	75	107	4227	0.056	30838	12.23	89	128	107	152
51069	60	81	2982	0.048	33787	10.47	50	83	68	97
51073	28	44	2340	0.030	30507	10.94	15	26	19	34
51111	9	21	844	0.077	24015	9.53	17	37	24	44
51113	12	17	799	0.037	29655	9.73	26	35	9	19
51127	6	8	875	0.028	38776	10.83	5	13	9	17

CNTY	$Q_{i,90}$	$V_{i,90}$	$T_{i,90}$	$U_{i,90}$	$M_{i,90}$	$E_{i,90}$	$Q_{i,85}$	$V_{i,85}$	$Q_{i,86}$	$V_{i,86}$
51149	41	62	2353	0.061	31783	12.01	24	41	42	61
51153	340	450	17321	0.026	52506	13.06	297	434	342	462
51183	9	27	820	0.057	28333	8.81	7	31	13	35
53013	6	7	261	0.093	28028	11.92	10	15	11	18
53017	32	43	1863	0.070	29863	12.11	26	40	39	64
53027	72	104	4368	0.091	29338	11.72	107	149	104	156
53039	29	50	1181	0.114	30123	11.68	26	51	36	53
53049	31	41	1117	0.081	26269	11.65	13	25	29	41
53051	18	25	659	0.126	27801	11.7	14	19	19	27
53075	26	35	5820	0.021	35444	13.87	28	38	65	83
54003	68	103	4135	0.072	30062	10.66	52	102	67	103
54009	35	57	2281	0.072	34880	10.97	46	88	51	90
54027	11	27	1247	0.114	25931	10.17	14	24	21	35
54043	26	42	1758	0.127	21459	9.05	13	34	22	44
54063	21	31	898	0.071	22626	10.09	12	18	13	26
54067	36	54	2103	0.138	22838	9.67	38	65	36	66
54085	12	18	773	0.124	23379	9.9	14	30	15	28
54089	17	31	933	0.110	19685	9.84	8	22	15	32
55001	13	22	918	0.058	24300	10.72	26	36	24	35
55007	20	27	965	0.065	22064	11.65	24	41	28	42
55047	17	26	1315	0.071	25774	10.94	21	29	22	40
55075	68	87	3024	0.067	25946	11.18	63	110	76	122
55113	20	26	983	0.067	21222	11.36	33	51	26	40
56015	18	25	929	0.045	24374	11.88	14	19	18	31
56029	45	58	1800	0.047	31742	12.5	25	39	54	71
56033	39	59	1606	0.052	33217	12.46	45	62	81	105
56035	9	12	316	0.038	29278	12.78	6	15	6	9
56039	14	19	680	0.021	31358	14.17	6	10	8	10

APPENDIX D

EXAMPLE SAS COMMAND FILE FOR REGRESSION ANALYSIS

```
OPTIONS LINESIZE = 80 ;
CMS FILEDEF EXTFIN DISK THESPRED DATA A;
TITLE 'REGRESSION: MARKET PREDICTION MODEL - USAREC;  MAJ. CELSKI';

/*this file contains the sas program used to perform the regression analysis on the quality
models, global 1 and global 2. The global 3 model requires additional code. The same type
file is used to perform the regression on the global 1 and 2 volume models. */


***************** import external file data *******************;

DATA one ;
INFILE EXTFIN ;
  INPUT
   fips      4- 9
   gsa90     10-14
   vol90     15-19
   target    20-26
   unemp     27-33
   medin     34-39
   avgedlvl  40-44
   gsa85     45-49
   vol85     50-54
   gsa86     55-59
   vol86     60-64 ;

* PROC PRINT DATA = one ;
* VAR fips gsa90 vol90 target unemp medin avgedlvl gsa85 vol85 gsa86 vol 86;

DATA two ; SET one ;


*************** linear regression models *****************;

/*newtargt = target/100 ;

PROC REG DATA = two ;
```

```
* MODEL gsa90 = newtargt medin avgedlvl unemp gsa85 gsa86/
    SELECTION = STEPWISE
    SLENTRY = 0.05
    SLSTAY = 0.05
    DETAILS ;

 *MODEL gsa90 =  newtargt gsa85 gsa86 /  DW R INFLUENCE ;
 *MODEL gsa90 =  newtargt gsa85 gsa86 /  DW NOINT ;
 *MODEL gsa90 =  newtargt  /  R   ;
 *MODEL gsa90 =  newtargt gsa86 /  DW ;
 *MODEL gsa90 =  gsa85 gsa86 / DW ;
 *MODEL gsa86 =  gsa85 / DW ;

 *PROC PLOT DATA = two;
 *PLOT gsa90*newtargt gsa90*gsa85 gsa90*gsa86 gsa86*gsa85;
 *     / VPLOTS = 2  HPLOTS = 2 ; */


****** regression models using transformed variables *******;

*delete observations with no gsa production;

  IF gsa90 = 0 THEN DELETE ;
  IF gsa85 = 0 THEN DELETE ;
  IF gsa86 = 0 THEN DELETE ;

  newgsa90 = LOG(gsa90) ;
* newgsa90 = gsa90**0.10 ;
  lntarget = LOG(target) ;
  lngsa85  = LOG(gsa85) ;
  lngsa86  = LOG(gsa86) ;

  PROC REG DATA = two ;

 *MODEL newgsa90 = lntarget medin avgedlvl unemp lngsa85 lngsa86/
    SELECTION = STEPWISE
    SLENTRY = 0.05
    SLSTAY = 0.05
    DETAILS ;

  MODEL newgsa90 = lntarget lngsa85 lngsa86 /  DW ;
 *MODEL newgsa90 = lntarget  / DW R ;
 *MODEL newgsa90 = lngsa85 lngsa86 / DW ;
```

```
************** print scatter plots ***********************;

*PLOT newgsa90*lntarget newgsa90*lngsa85 newgsa90*lngsa86
     newgsa90*avgedlvl;
*    / VPLOTS = 2  HPLOTS = 2 ;


********* check residuals for normality *******************;

OUTPUT OUT = out2  R = resid2 ;
PROC UNIVARIATE FREQ PLOT NORMAL ;
VAR resid2 ;

PROC PRINT DATA = OUT2 ; VAR resid2 ;
```

APPENDIX E

MEAN RELATIVE ERROR

MEAN RELATIVE ERROR (QUALITY)

		GLOBAL 1		GLOBAL 2		GLOBAL 3	
COUNTY	ACTUAL	PRED	ERROR	PRED	ERROR	PRED	ERROR
1127	78	72	0.079	79	0.007	78	0.005
4027	101	116	0.144	137	0.359	134	0.326
5133	15	16	0.054	17	0.116	14	0.042
6019	505	580	0.149	645	0.277	543	0.076
8089	28	32	0.130	24	0.150	27	0.021
9007	111	136	0.226	144	0.295	149	0.346
10001	167	159	0.050	132	0.207	137	0.177
12099	688	636	0.076	699	0.016	845	0.228
13293	23	34	0.467	30	0.300	27	0.177
16045	22	17	0.225	13	0.400	16	0.270
17143	191	241	0.264	197	0.029	197	0.032
18115	4	8	0.916	6	0.528	7	0.760
19061	116	127	0.098	104	0.104	107	0.079
20065	2	3	0.701	4	0.847	4	1.170
21197	9	15	0.629	15	0.711	13	0.458
22055	286	214	0.252	197	0.312	212	0.260
23027	47	47	0.002	36	0.227	51	0.082
24037	120	88	0.270	89	0.262	89	0.262
25005	437	480	0.099	443	0.014	361	0.173
26099	605	743	0.229	726	0.200	691	0.142
27091	32	29	0.085	24	0.262	26	0.195
28083	36	47	0.292	50	0.380	47	0.309
29183	293	253	0.137	237	0.191	236	0.195
30093	68	52	0.236	36	0.469	40	0.413
31007	2	1	0.460	1	0.438	1	0.307
32019	33	21	0.359	19	0.416	21	0.357
33015	321	272	0.152	264	0.178	241	0.250
34005	352	424	0.204	431	0.224	354	0.004
35009	67	60	0.103	51	0.232	55	0.178
36103	1047	1363	0.302	1468	0.402	924	0.117
37159	91	104	0.138	112	0.229	114	0.255
38071	15	18	0.216	15	0.022	16	0.088
39083	55	69	0.254	64	0.168	67	0.224
40103	13	11	0.147	12	0.111	10	0.262
41045	37	39	0.056	32	0.145	35	0.042
42095	187	262	0.400	264	0.410	241	0.286
44005	70	96	0.373	92	0.317	105	0.507
45041	156	132	0.156	131	0.158	136	0.127
46135	5	23	3.508	20	3.053	22	3.451
47031	59	52	0.124	44	0.248	42	0.294
48201	2692	2733	0.015	2662	0.011	3635	0.350
49001	2	4	1.220	6	1.956	8	2.882

COUNTY	ACTUAL	GLOBAL 1 PRED	GLOBAL 1 ERROR	GLOBAL 2 PRED	GLOBAL 2 ERROR	GLOBAL 3 PRED	GLOBAL 3 ERROR
50027	54	60	0.111	54	0.007	70	0.292
51087	204	172	0.155	199	0.023	215	0.053
53005	166	139	0.163	112	0.326	111	0.330
54101	8	14	0.731	14	0.725	12	0.454
55035	113	127	0.122	125	0.107	128	0.130
56041	40	22	0.447	22	0.443	26	0.355
	TOTAL MRE:		15.726		17.011		17.796

MEAN RELATIVE ERROR (VOLUME)

COUNTY	ACTUAL	GLOBAL 1 PRED	GLOBAL 1 ERROR	GLOBAL 2 PRED	GLOBAL 2 ERROR	GLOBAL 3 PRED	GLOBAL 3 ERROR
1127	130	117	0.100	119	0.083	122	0.061
4027	143	166	0.160	208	0.457	198	0.387
5133	34	24	0.282	25	0.253	25	0.279
6019	863	864	0.001	978	0.134	816	0.054
8089	43	43	0.003	36	0.160	40	0.072
9007	179	197	0.102	218	0.219	223	0.245
10001	250	236	0.057	201	0.196	210	0.160
12099	955	907	0.050	1061	0.111	1182	0.238
13293	35	53	0.513	45	0.297	45	0.279
16045	34	27	0.192	20	0.411	23	0.315
17143	290	351	0.212	298	0.029	297	0.023
18115	11	11	0.020	9	0.156	9	0.188
19061	148	178	0.202	158	0.065	156	0.053
20065	6	6	0.008	6	0.065	5	0.105
21197	13	25	0.916	23	0.798	22	0.730
22055	406	325	0.200	299	0.264	317	0.219
23027	59	70	0.181	55	0.065	68	0.152
24037	170	124	0.269	134	0.210	138	0.187
25005	703	731	0.040	672	0.043	589	0.162
26099	865	1057	0.222	1101	0.273	1109	0.282
27091	41	42	0.035	36	0.126	35	0.148
28083	83	85	0.025	75	0.091	76	0.086
29183	389	354	0.091	360	0.076	358	0.079
30093	97	76	0.214	55	0.435	58	0.398
31007	2	2	0.144	2	0.146	2	0.192
32019	43	32	0.267	29	0.319	28	0.338
33015	431	365	0.152	401	0.071	377	0.126
34005	535	633	0.184	654	0.222	575	0.075
35009	91	90	0.014	78	0.142	81	0.112
36103	1525	2018	0.324	2228	0.461	1659	0.088
37159	149	160	0.077	170	0.139	176	0.182
38071	25	25	0.001	22	0.109	22	0.135
39083	77	101	0.311	97	0.266	96	0.245
40103	19	16	0.161	18	0.077	17	0.122
41045	57	59	0.028	48	0.158	52	0.092
42095	272	385	0.417	400	0.472	376	0.384
44005	96	143	0.487	140	0.457	152	0.581
45041	255	220	0.139	199	0.218	208	0.183
46135	8	32	2.949	31	2.846	30	2.743
47031	80	78	0.030	67	0.158	67	0.157
48201	3936	4066	0.033	4040	0.027	4740	0.204
49001	5	6	0.250	9	0.795	11	1.233
50027	78	85	0.094	83	0.058	96	0.234
51087	292	246	0.156	303	0.036	321	0.100
53005	166	192	0.156	170	0.023	164	0.009
54101	12	19	0.618	21	0.745	20	0.671
55035	152	173	0.135	190	0.249	188	0.237
56041	48	32	0.334	34	0.295	38	0.217
	TOTAL MRE:		11.555		13.507		13.562

APPENDIX F

GAMS MODEL AND DATA FOR RALEIGH BATTALION

```
*---------------------------------------------------------------------
$OFFUPPER  OFFSYMLIST  OFFSYMXREF
OPTIONS  LIMROW = 0, LIMCOL = 0, SOLPRINT = OFF, DECIMALS = 2,
         RESLIM = 10000, ITERLIM = 900000, OPTCR = 0.10;
OPTIONS  INTEGER1 = 6 ;
*---------------------------------------------------------------------
$ONTEXT
  model for thesis, formulated nov 91 - jan 92 by
      student: MAJ Robert J. Celski
      advisor: DR S. Lawphongpanich

  the objective function in the model:

  assigns counties to potential company headquarter's in
  an optimal manner, by minimizing the distance from the
county to
  the company, penalizing deviations from the quality and
volume
  enlistment goals, and penalizing the opening up and closing
down
  of certain company headquarters.

  the constraints in the model:

   1.     ensure that each company has comparable workload by
          penalizing deviations from a quality and volume goal
          that is predicted using regression models.

   2.     assign each county to only one company.

   3.     limit the number of companies in a battalion.

   4.     ensure counties are assigned only to companies that
          are opened.

   5.     ensure counties are assigned to the company that is
          located in the county, if that company is open.

   6.     ensure that the deviation from the production goal
          for each company is within a certain fixed
          percentage.
```

```
offtext
*-------------------------------------------------------------
SETS

   I  counties in the state /

$INCLUDE RALEIGH.FIP
    /

   J  existing and potential companies /
$INCLUDE RALEIGH.COM
   /  ;

$INCLUDE RALEDIST.PRN

SCALARS

$INCLUDE RALEIGH.SCA
;

PARAMETERS

$INCLUDE RALEIGH.PEN
;


PARAMETER

     PQUAL(I)   predicted quality production of county i in
1992 /
$INCLUDE RALEQUAL.PRN
/;

PARAMETER

     PVOL(I)  predicted volume production of county i  in 1992
/
$INCLUDE RALEVOL.PRN
/;


SCALAR
     QGOAL     quality goal for each company based on equity
;
     QGOAL  =  SUM(I, PQUAL(I)/NHQ) ;

SCALAR

     VGOAL    volume goal for each company based on equity ;
     VGOAL  =  SUM(I, PVOL(I)/NHQ) ;
```

```
SCALAR
     AVGQ       overall county average quality produced ;
     AVGQ =     SUM(I, PQUAL(I))/CARD(I);


PARAMETER CODE(I) /
$INCLUDE RALECODE.PRN
/ ;


VARIABLES

  X(I,J)     equals 1 if county i is asgn to company j - 0
             otherwise

  Y(J)       equals 1 if company hq is used - 0 otherwise

  (J)      elastic variable used to penalize the missing (over
           * achieving) of the quality goal in the objective
           function

  ZM(J)    elastic variable used to penalize the missing
           (under * achieving) of the quality goal in the
           objective function

  WP(J)    elastic variable used to penalize the missing (over
           * achieving) of the volume goal in the objective
           function

  WM(J)    elastic variable used to penalize the missing
           (under * achieving of the volume goal in the
           objective function

  Z        objective function value - unit less  ;


POSITIVE VARIABLES  ZP, ZM, WP, WM ;

  ZP.UP(J) = VAR*QGOAL;
  ZM.UP(J) = VAR*QGOAL;
  WP.UP(J) = VAR*VGOAL;
  WM.UP(J) = VAR*VGOAL;
```

```
BINARY VARIABLES  X, Y ;

  * special command requirements placed here (ie, a certain
  * company must remain open etc, (in this case, keep raleigh
  * company open)

  Y.FX('RAL') = 1.0;

  * assign value of 0 to xij variables if dij = -1 in table
    above
  X.FX(I,J) $(D(I,J) EQ -1) = 0 ;

EQUATIONS

  TOTVAL          relative value of the objective function
  COUNTYASGN(I)   each county assigned to only 1 company
  FIXCOMPANY      fix the number of companies in a battalion
  CHECKASGN(I,J)  assign counties only to open companies
  FIXASGN(I,J)    assign counties to open co's that contain
                  them
  QUALGOAL(J)     elasticize  the  qual  goal  -  penalize
                  deviations
  * SAME(J)
  VOLGOAL(J)      elasticize  the  vol  goal  -  penalize
                  deviations;

TOTVAL ..    Z =E= SUM((I,J),(PQUAL(I)/AVGQ)*D(I,J)*X(I,J)) +
                   200*QUALPRCNT/QGOAL*(SUM(J, ZP(J)+ZM(J))) +
                   200*VOLPRCNT/VGOAL*(SUM(J, WP(J)+WM(J))) +
                   SUM(J, PENOPEN(J)*Y(J)) +
                   SUM(J, PENCLOSE(J)*(1-Y(J)))   ;

COUNTYASGN(I) ..    SUM(J,X(I,J)) =E= 1 ;

FIXCOMPANY ..       SUM(J,Y(J)) =E= NHQ ;

CHECKASGN(I,J) ..   X(I,J) =L= Y(J);

FIXASGN(I,J) $ (D(I,J) EQ 0) .. X(I,J) =E= Y(J) ;

QUALGOAL(J) .. SUM(I, PQUAL(I)*X(I,J))+ZP(J)-ZM(J) =E= QGOAL
*Y(J) ;

VOLGOAL(J) ..  SUM(I, PVOL(I)*X(I,J))+WP(J)-WM(J) =E= VGOAL
*Y(J) ;

MODEL  ALINMENT  /ALL/ ;

SOLVE ALINMENT USING  MIP MINIMIZING Z;
```

```
*-----------------------OUTPUTFORMAT----------------------

PARAMETER  COST(*)
     QUALRSLT(J,*) number of quality contracts in company
     VOLRSLT(J,*)  number of volume contracts in company;

    QUALRSLT(J,'ACTUAL')    = SUM(I,PQUAL(I)*X.L(I,J)) ;
    VOLRSLT(J,'ACTUAL')     = SUM(I,PVOL(I)*X.L(I,J)) ;
    QUALRSLT(J,'GOAL')      = QGOAL*Y.L(J) ;
    VOLRSLT(J,'GOAL')       = VGOAL*Y.L(J) ;
    QUALRSLT(J,'% DIFF')$(QUALRSLT(J,'GOAL') NE 0) =
               100*(QUALRSLT(J,'ACTUAL')-QUALRSLT(J,'GOAL'))/
                          QUALRSLT(J,'GOAL') ;
    VOLRSLT(J,'% DIFF')$(VOLRSLT(J,'GOAL') NE 0) =
                100*(VOLRSLT(J,'ACTUAL')-VOLRSLT(J,'GOAL'))/
                          VOLRSLT(J,'GOAL') ;
    QUALRSLT(J,'COUNTIES') = SUM(I,X.L(I,J)) ;
    QUALRSLT(J,'1.5 MSN')  = (QUALRSLT(J,'ACTUAL')*0.4)/18 ;
    QUALRSLT(J,'1.0 MSN')  = (QUALRSLT(J,'ACTUAL')*0.4)/12 ;
    VOLRSLT(J,'COUNTIES')  = SUM(I,X.L(I,J)) ;
SET OPEN(J) companies to be opened ;
    OPEN(J) = YES$(Y.L(J) EQ 1) ;

PARAMETER ASSGNMNT(I,J) assignment of counties to companies ;
          ASSGNMNT(I,J)     = CODE(I)*X.L(I,J) ;

DISPLAY OPEN, QUALRSLT, VOLRSLT ;

OPTION: DECIMALS = 0 ;
DISPLAY ASSGNMNT ;
*ASSGNMNT(I,J) = CODE2(I)*X.L(I,J) ;

*DISPLAY ASSGNMNT ;
```

SAMPLE DATA FILES IMPORTED INTO THE ABOVE GAMS FILE USING $INCLUDE STATEMENTS:

FILE TITLE: Raleigh.fip (Lists the 100 county codes)

37001
37003
37005
.
.
.
37195
37197
37199

FILE TITLE: Raleigh.com (Lists 6 candidate headquarters - Burlington omitted)

FAY
GRN
RAL
WIN
ASH
CHN
BUR

FILE TITLE: Raledist.prn (Distances from counties to companies)

TABLE D(I,J) raleigh battalion distance from county i to company j

	FAY	GRN	RAL	WIN	ASH	CHN	BUR
37001	-1	108	42	48	-1	101	0
37003	-1	-1	-1	55	80	52	-1
37005	-1	-1	180	55	134	90	96
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
37195	70	30	44	-1	-1	-1	-1
37197	-1	-1	114	26	129	64	73
37199	-1	-1	-1	116	23	95	-1

FILE TITLE: Raleigh.sca (Various scalar values)

NHQ	number of company hqs used in the state	/ 6 /
QUALPRCNT	quality percent factor in the obj function	/ .8 /
VOLPRCNT	volume percent factor in the obj function	/ .2 /
VAR	max allowable deviation from co prod goal	/.20 /

FILE TITLE: Raleigh.pen (Costs of opening and closing companies)

PENOPEN(J) penalty cost assessed to open a new company

```
/ FAY       0
  GRN       0
  RAL       0
  WIN       0
  ASH       0
  CHN       0
  BUR    5660  /
```

PENCLOSE(J) penalty cost assessed to close an existing company

```
/ FAY       0
  GRN       0
  RAL       0
  WIN    8800
  ASH       0
  CHN       0
  BUR       0 /
```

FILE TITLE: Ralequal.prn (Predicted 1995 quality contracts)

```
37001  103
37003   24
37005    9
  .      .
  .      .
  .      .
37195   68
37197   26
37199   14
```

FILE TITLE: Ralevol.prn (Predicted 1995 volume contracts)

37001	146
37003	46
37005	14
.	.
.	.
.	.
37195	108
37197	42
37199	24

FILE TITLE: Ralecode.prn (Code relating FIPS to state maps)

37001	71
37003	24
37005	32
.	.
.	.
.	.
37195	83
37197	30
37199	12

LIST OF REFERENCES

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